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USSR Report

SPACE BIOLOGY AND AEROSPACE MEDICINE

Vol. 16, No. 6, November-December 1982

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Translation of the Russian-language bimonthly journal KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA published in Moscow by Izdatel'stvo "Meditsina".

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SPACE MEDICINE BENEFITS TO SCIENCE AND HEALTH CARE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 6, Nov-Dec 82 (manuscript received 31 May 82) pp 4-6

[Article by B. S. Alyakrinskiy]

[Text] In December 1922, the Union of Soviet Socialist Republics--the first united multinational state of workers and peasants in the history of mankind--was founded by the will of all peoples of our country.

The [illegible] years have been marked with such rapid development of the Soviet Union [illegible] the areas of industry, agriculture, science and culture, such intensive progress in all areas of our life that we can understand foreign specialists who either refuse to believe in the accomplishments of the building of socialism or speak of a miracle, in amazement at their scope.

The revolutionary and transforming work of the peoples united in the USSR resulted in establishment of a new type of social system, a developed socialist society.

At the present time, our multinational state is in the lead in worldwide economics, technology, culture, science, and it is demonstrating with indisputable conviction the advantages of the socialist regime which offers infinite opportunities for the creative initiative of the real history makers, the working masses. The Great October Socialist Revolution, which inaugurated a new era in the development of mankind, advanced as the main objective of revolutionary transformation of the world the happiness of each working member of society. At the 3d All-Russian Congress of the Soviets, V. I. Lenin stressed this task with utmost clarity: "Previously, all human intelligence, all of human genius created only for the purpose of providing all of the benefits of technology and culture to some and to deprive others of the essentials--education and development. At the present time, however, all of the miracles of engineering [technology] and all of the conquests of culture will become the heritage of all, and from now on never will the human mind and genius be converted into the means of coercion, the means of exploitation."*

In its struggle for the future, our party regarded and continues to regard the real welfare of man, his spiritual and physical health to be of paramount

*V. I. Lenin, "Complete Collection of Works," 5th ed., Vol 35, p 289.

importance. For expressly this reason, medicine--the science that is specially called upon to solve such problems--occupies a place of honor on the general front in the struggle for the building of a communist society. And it is solving them well; all of its directions, all of its numerous areas of endeavor are governed by this noble goal. Space medicine, a branch that would appear to be so remote from earthly concerns, is a vivid example. This "extraterrestrial" daughter of medicine, which directs itself toward solivng problems raised by space exploration, is making a ponderable and significant contribution to development of health care on earth.

Weightlessness is justifiably considered the principal problem of space medicine. In his everday life, man does not have occasion to encounter weightlessness. For expressly this reason, active investigation of weightlessness was linked with the start of practical exploration of space. Several studies established that there are distinctive reactions to conditions that either create real weightlessness (spaceflight) or that simulate it to some degree or other (clinostatic and antiorthostatic [head down] hypokinesia, immersion). Most attention in these studies was given to reactions of the cardiovascular and muscular systems, as well as mineral metabolism. As a result of this research, recommendations were elaborated to minimize the deleterious effect of weightlessness on man, implementation of which turned out to be exceptionally effective, as confirmed by the successful completion by Soviet cosmonauts of long-term (up to 185 days) orbital flights. On the threshold of the first space flights, the conception was formed that weightlessness had a terrible, devastating force with regard to living systems, and the term, "space scarecrow," was even coined by someone for it. At the present time, there are all grounds to announce that there is one "scarecrow" less in space, although there is still quite a bit of work to do in this direction.

The solution to one of the most important problems of space medicine also has positive significance to ground-based medicine, which constantly encounters the negative effects of hypokinesia (diminished muscular activity, relative passivity of the muscular system). In a real spaceflight, hypokinesia attains a marked degree, primarily due to weightlessness, as well as because of considerable restriction of cosmonauts' motor activity (the small size of spacecraft cabins, prolonged maintenance of a relatively unchanged position, minimal exertion involved to handle controls are contributing factors). In space, there is a specially developed system of exercises to prevent hypokinesia.

In clinical practice, the physician often has occasion to observe the negative effects of hypokinesia: in the presence of diverse types of severe trauma (fractures, significant injury to viscera), diseases of the musculoskeletal system and many other diseases (including infectious ones) that limit movement. The physician is also concerned with hypokinesia in the area of preventive medicine, since in our times of scientific and technological revolution man is increasingly often deprived of the opportunity to experience adequate physical loads. Many types of modern labor have changed into monotonous "button-pushing" operations. The wide use of public and private transport as a means of conveyance and many of the "conveniences" in our everyday life deprive man of the daily standard of exercise that is required. For expressly this reason, it would be difficult to overestimate the relevance of data obtained about hypokinesia in

space medicine and recommendations elaborated on their basis to control its negative effects: they are finding direct applications in terrestrial medicine to correct this state.

Exploration of space was not only instrumental in intensifying research on problems already known to medicine, but initiated directions of scientific research that are actually new scientific disciplines. There is complete justification for including among such directions space biorhythmology, which is the science dealing with biological rhythms of man and animals displaced from earth into space. The very first manned flights in near-earth orbits showed that it was important to take into consideration, when planning such missions, the laws of biological rhythms of the body and, first of all, those that were named circadian (close to 24-h) rhythms, the period of which is either 24 h or close to this. Intensive research in space biorhythmology established several theses of theoretical and practical importance. In particular, the following was determined: circadian rhythms are referable to the endogenous rhythms of the body; any disruption of coordination of these rhythms is associated with negative phenomena, combined in the concept of desynchronosis; desynchronosis is a mandatory element, as well as the earliest component of the general adaptation syndrome, and it accompanies any type of stress, no matter what has caused it; the state of circadian rhythms of the body is a reliable universal criterion of its general functional state; adaptation processes are governed by the law of fluctuation [undulation]; endurance of the same loads (including those used in so-called functional tests, which are performed extensively in clinical and expertise practice) is not the same at different times of day. The patterns established in space biorhytmology served as the basis for regulating life aboard orbital vehicles, while many of them have gained recognition and are used in terrestrial medicine, in particular, in scheduling shift-type work in industry, as well as clinical practice.

The incursion into space, which became possible thanks to the rapid progress of industry and science, stimulated considerably interest in the problem of healthy man, to which considerably less attention was given in terrestrial medicine than to the problem of sick man, although it became virtually traditional to state that all diseases are based on the functional patterns of all systems in the healthy body which, it would seem, should prompt just as much attention to investigation of the phenomenon of health as disease. However, this did not happen, as if mankind postponed handling this problem until the start of the space age.

Preparation for the first manned orbital flights raised a number of questions with exceptional acuity, which pertained to screening candidates for spaceflights, "normal" parameters for healthy man, the range of this "norm" that must be considered to guarantee successful performance by cosmonauts of the tasks put to them. Mobilization of all previously known methodological approaches to determination of the physiological reliability of the human body, demonstration of well-compensated ailments and development of new ways and means of establishing such reliability was required to answer these questions, and it included in particular methods for detecting latent coronary insufficiency, determining reactivity of the vestibular system, etc. Within a short period of time, the system of professional screening of cosmonauts was defined in its main features and it was reliably backed up with regard to methods, which made

it possible to predict with great certainty the results of fulfilling flight programs. At the same time, the advances made in this direction by space medicine found broad application in terrestrial medical (clinical) practice, primarily in cases where it is required to detect latent pathology and diverse types of compensated diseases.

As we know, medical monitoring of cosmonauts during flights is effected with the use of several sources of adequate information, among which telemetric recording of the main physiological parameters characterizing the current functional state of the body plays a most important part. The difficulties involved in using such registration under flight conditions required much effort, persistent research and numerous trials, as a result of which a system of medical telemetry was created that met the necessary requirements. The medical telemetry system that is used in space also found applications on earth--in special experiments, sports practice, i.e., in situations where it is difficult or impossible to pick up the needed information directly.

These are some of the most important problems facing Soviet space medicine.

The novelty of man's penetration into space, intensive creative searchers and solution of the most difficult problems advanced by this incursion distinguish the inception and development of one of the newest scientific directions of our times--space medicine. Space medicine, which is stimulated by the rapid progress of science and demands of cosmonautics, has achieved some major accomplishments, which are indicative of the fact that it is "in step" with development of the hardware for space travel. As it solved its own special problems, space medicine also made a major contribution to work on problems having a direct bearing on the concerns of terrestrial medicine.

On the 60th anniversary of the formation of the USSR, space medicine has approached achievements that are a reliable guarantee for further progress of our country in the area of space exploration.

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THE EARLY STAGE OF DEVELOPMENT OF COSMONAUTICS IN THE USSR (1917-1945)

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 6, Nov-Dec 82 (manuscript received 28 Jan 82) pp 7-15

[Article by Ye. P. Tolmachev]

[Text] "... What we have achieved in space exploration is not to be credited to individuals, but to the entire people, our party, the party of Lenin" (S. P. Korolev).

Our country is properly considered the birthplace of cosmonautics. As we know, the works of the outstanding Russian scientist, K. E. Tsiolkovskiy (1857-1935) [1] originated scientific theory of spaceflights; he was the first to validate the possibility of using rockets for interplanetary travel; he pointed to the optimum routes of development of cosmonautics and rocket building, and he found several important engineering designs for rockets and liquid-propellant rocket engines (LRE). Much credit is due in the history of Russian rocket technology to military engineers A. D. Zasyadko (1779-1837) and K. I. Konstantinov (1817-1871), as well as the well-known member of the Populist People's Freedom Party, N. I. Kibal'chich (1853-1881), the Russian scientists and engineers N. Ye. Zhukovskiy (1847-1921), I. V. Meshcherskiy (1869-1935), F. A. Tsander (1887-1933), Yu. V. Kondratyuk (1897-1942), V. V. Vetchinkin (1888-1950) and M. K. Tikhonravov (1900-1974). Academicians S. P. Korolev (1907-1966) and M. V. Keldysh (1911-1978), as well as many other Soviet scientists and builders played an enormous part in development of space-rocket technology.

The flight of Yu. A. Gagarin and other historic feats in space exploration became possible thanks to the fact that, in the USSR, under the leadership of the Leninist Party, tremendous efforts were undertaken to create a powerful and well-organized industry, well-developed modern technology and unprecedented flourishing of Soviet science.

In the history of cosmonauts, the period from 1917 to 1945 is of considerable interest; this is when some important research and experiments were conducted in many branches of science and engineering; the first scientific research and planning-designing organizations were founded in the area of rocket technology, and highly qualified engineering and scientific personnel were trained.

We can single out 4 main stages in the development of rocket technology in 1917-1945, each of wich had its own distinctions due to the situation in our country,

development of the economy, degree of dissemination of ideas of cosmonautics, level of theoretical and practical development of rockets and their most important systems, nature of institutions and organizations working in this field.

First stage (1917-1928). At this stage, the conditions were created for development of space-rocket technology.

From the very first days of the Great October Revolution, in spite of the extremely difficult conditions in our country (civil war, hunger, devastation, backwardness, poverty), V. I. Lenin, the Party and Soviet government devoted much attention to development of science. V. I. Lenin demanded that science "... not be left as a dead letter or fashionable phrase.... that science be indeed contained in flesh and blood, be changed into a complete and real constituent of everyday life" [2]. He emphatically criticized "leftist" phrase-mongers, vulgarizers and all those who denied, under the guise of revolutionism, the profound continuity of development of culture, science and technology. V. I. Lenin wrote: "All the culture that capitalism has left should be taken and socialism built from it. All science, technology, all knowledge and art must be taken. Without this we cannot build the life of a communist society" [3].

In April 1918, V. I. Lenin wrote his famous "Outline of a Plan of Scientific and Engineering Work," in which specific and distinct tasks were defined for Soviet science, as well as the principal and immediate tasks for technological and economic progress; the main directions of work covering a period of many years were spelled out [4].

At the same time (in April 1918), at the suggestion of V. I. Lenin, the Sovnarkom [Council of Peoples' Commissars] adopted a decree concerning the work of the Academy of Sciences for studying the productive forces of the country and expedient location of industry. Appropriate funds were allocated for this purpose. The decisions of the 8th through 15th Party Congresses had an enormous influence on development of work in new areas of engineering at the first stage.

In March 1919 at the 8th Congress of the RKP(b) [Russian Communist Party (of Bolsheviks)] approved the second Party program, in which it was stated that it was imperative to bring science closer to industry, the task was put of creating an entire network of applied scientific institutes, laboratories, experimental stations, experimental industries to test technological methods, improvements and inventions, to keep records of and to organize all scientific resources [personnel] and equipment.

Starting in 1918, when the conditions in the Soviet Republic were exceptionally difficult, by instruction of V. I. Lenin and the Party, scientific institutions dealing with the most important branches of natural sciences began to be organized: physicotechnical and optical institutes in Petrograd, radio engineering laboratory, physicomathematical institute of the Academy of Sciences in Nizhniy Novgorod (Gorkiy) and the Radium Institute in Petrograd.

In the 1920's, scientific institutions were created under the VSNKh [Supreme Council of the National Economy], which were of important applied significance,

in particular the electric engineering and heat engineering institutes. During the years of the civil war, 117 scientific institutions were organized, which united within their walls many scientists and specialists. Thanks to the untiring concern of the Party, these institutes subsequently became the largest centers of progressive science. The enormous magnetic and creative force of the revolution was one of the important reasons why there was mass scale movement of the old intelligentsia to the side of the struggling proletariat. It was noted in the decree of the CPSU Central Committee "On the 60th Anniversary of the Great October Socialist Revolution" that "The broadest masses of working people, all progressive people of science and culture followed the revolution, the working class" [5].

V. I. Lenin and the Party offered every support and assistance to scientists and inventors.

The Party created conditions for fruitful and creative work for K. Tsiolkovskiy, N. Ye. Zhukovskiy, S. A. Chaplygin, A. N. Tupolev, N. N. Polikarpov, D. P. Grigorovich, V. P. Vetchinkin and many other prominent scientists and engineers. The Sovnarkom adopted a decree on 9 November 1921, with the personal participation of V. I. Lenin, in which it was stated: "In view of his special merits, K. E. Tsiolkovskiy, the scientist-inventor and specialist in aviation, is to be granted a lifelong pension..." [6]. In so doing, the worker and peasant state not only recognized the vitality and potential of the views of the "dreamer from Kaluga," but drew the attention of the broad community to his works. In his autobiography, K. E. Tsiolkovskiy wrote: "Under the Soviet government and assured of a pension, I was able to devote myself freely to my work and, having been almost unnoticed before, I now stirred up attention to my work." In 1926-1929, K. E. Tsiolkovskiy developed theory of movement of stage rockets or rocket trains. He was the first to examine the biomedical problems that arise during long-term spaceflights. While K. E. Tsiolkovskiy had written 130 works before the Great October Socialist Revolution, he wrote more than 600 in the years of Soviet power.

Many of the engineering concepts expounded by this great scientist have found applications in development of modern rocket engines, space rockets and vehicles. K. E. Tsiolkovskiy has become part of the history of science forever, not only as the founder of theoretical cosmonautics, but as a fervent patriot of his homeland, an ardent disseminator of ideas of cosmonautics. His works cover a wide range of problems in the areas of aerodynamics, rocket dynamics, theory of aircraft and dirigibles, as well as biology, philosophy, linguistics, etc.

F. A. Tsander [7] was another scientist in whose work V. I. Lenin was interested. F. A. Tsander devoted his entire life to rocket building and cosmonautics. He was one of the originators of rocket building in our country, an outstanding design engineer, an ardent adherent, advocate and popularizer of space navigation. F. A. Tsander conducted theoretical studies of flights of aircraft--rockets and their equipment, he calculated the thermodynamic cycles of rocket, jet engines, and others. In 1930, F. A. Tsander built the first Soviet laboratory jet engine, the OR-1 (experimental jet) based on an ordinary soldering lamp, which he tested with compressed air with gasoline. In 1931-1933, he was engaged in development of liquid-propellant rocket engines.

In 1917-1919, Yu. V. Kondratyuk, the talented and naturally gifted inventor, independently of K.E. Tsiolkovskiy wrote out the main equations of rocket propulsion, examined problems of energetically most advantageous trajectories of spaceflights and theory of flight of multistage rockets; he also developed a number of problems of rocket dynamics and rocket building.

In early 1921, work on rocket technology was included in the system of state planning and financing. In Moscow, a special laboratory subordinated to one of the departments of VSNKh was opened to implement the inventions of engineer N. I. Tikhomirov (1860-1930). In this laboratory, promising work was done on creating solid-fuel jet-propelled missiles. Later on, this work resulted in creation of rocket missiles for the famous "Katyusha."

In 1925, this laboratory was relocated in Leningrad. The work begun there continued to be developed and gained the support of S. M. Kirov, secretary of the Leningrad Obkom of VKP(b) and M. N. Tukhachevskiy commander of the Leningrad Military District.

The first major achievements were made in this laboratory in 1928: successful testing of rocket missiles with smokeless trotyl-pyroxylin powder. That same year, the laboratory was converted into the Gas Dynamics Laboratory (GDL), which provided conditions for complex work. This is how the rocket organization started, and it played a large part in implementing planned research and testing in the USSR in the area of rocket building.

It was difficult to develop the rocket and, later, the space rocket technology without development of aviation. History has shown that the knowhow and achievements of aviation science and technology were used extensively in rocket production. Many rocket designers of our country had an aviation education, they had designed and built aircraft. Anticipating the enormous influence that development of flying machines would have on all branches of science, culture and the national economy, V. I. Lenin called the 20th century "the century of airplanes, electricity and motor vehicles" [8].

Under the guidance of V. I. Lenin and the Party, the foundation of the air power of our country was laid in the early years of Soviet power, and there was reinforcement of the material base of aviation, as well as education and training of aviation personnel. In 1917-1922 alone, more than 100 Party and state documents dealing with aviation were approved, with the personal participation of V. I. Lenin [9].

The establishment (on 1 December 1918) of the Central Aerohydrodynamic Institute (TsAGI) at the instructions of V. I. Lenin was an important step in the development of Soviet science and technology [10]. Later on, the Central Institute of Aircraft Engines (TsIAM), All-Union Institute of Aviation Materials and others separated from the TsAGI into independent institutions. The TsAGI gave life to many design offices [11].

In 1920, an experimental research airport was created, where the State Scientific Research Institute of the Air Forces was soon deployed to test aviation equipment. The name of V. I. Lenin is linked with the establishment in 1920 of aviation's first higher educational establishment, which was converted into the Air Force

Academy imeni Professor N. Ye. Zhukovskiy. This academy gave a start in life to more than one generation of prominent aircraft designers and developers of rocketry.

Development of aviation and other new branches of engineering required great effort and resources of the young Soviet state encircled by a hostile environment. At the initiative and under the direct leadership of the Party, a movement was deployed in the country under the slogan of "Working people, build an Air Force!" [12].

On 8 March 1923, a voluntary Society of Friends of the Air Fleet (ODVF) was founded in Moscow, and its main objects were as follows: to deploy a national campaign for the building of a powerful air fleet, to organize the collection of funds to build aircraft, to eradicate ignorance in the area of aviation among the public, to popularize ideas of aviation in the press. This society was instrumental in development of mass scale airplane model and glider sport. It organized several propaganda flights in the country. Two years later, there were 25,000 ODVF cells in the USSR, consisting of 2 million people. It should be noted that in its work the ODVF devoted much attention to questions of rocket building and ideas of cosmonautics. The ODVF was the foundation on which the patriotic Osoaviakhim Society [society for the promotion of defense, furthering of aviation and the chemical industry] was subsequently created.

The most recent studies of historians indicate that not only questions of aviation, air navigation, but rocket engineering and cosmonautics aroused interest in our country in the 1920's. This is indicated by the numerous attempts to form associations of enthusiasts of rocketry and interplanetary flights. One of the largest such associations was formed in May 1924 under the Military Scientific Society of the Air Force Academy (presently the Air Force Engineering Academy imeni N. Ye. Zhukovskiy) under the name of the world's first Society for the Study of Interplanetary Travel, which about 200 people joined.

This society developed by-laws and elected a presidium consisting of V. P. Kaperskiy, M. G. Leytezen, M. A. Rezunov, M. G. Serebrennikov, F. A. Tsander and V. I. Chernov. G. M. Kramarov, the publicist and Leninist-bolshevik, was appointed as its president. K. E. Tsiolkovskiy, V. P. Vetchinkin, M. Ya. Lapirov-Skoblo, Ya. I. Perel'man, A. K. Belyayev and other scientists, specialists and journalists participated in the work of this society.

The Society for the Study of Interplanetary Travel had a short existence (it broke up in autumn of 1924), but it played an important part in popularizing information about space in our country, it united the efforts of gifted engineers and designers around problems of cosmonautics.

In 1925, Academician D. A. Grave (1863-1939) created a circle in Kiev for the study of world space. History's first exhibit dealing with the problem of studying world space was organized in June 1925 through the efforts of the Kiev circle and invetors' section of the Kiev Association of Engineers and Technicians.

The first world exhibit of models of interplanetary vehicles, equipment, instruments and historic material, which was organized in 1927 in honor of the

10th anniversary of the Great October Socialist Revolution, in Moscow, on Tverskaya Street (presently Gor'kiy Street), was another major event that had appreciable influence on propagandizing cosmonautics. Scientific works, models of rockets and interplanetary craft of K. E. Tsiolkovskiy, F. A. Tsander, N. I. Kibal'chich, the inventors A. Ya. Fedorov, G. A. Polevoy and G. F. Kreyn, as well as foreign researchers Max Val'ye, Walter Goman, Herman Obert (Germany), R. Esnault-Pelterie (France), Robert Goddard, Nichols, Gulya (United States), Ulinsky, Lademan (Austria), Welch (England) and others were exhibited there. The exhibition was open for more than 20 months and enjoyed much success. In this time, more than 10,000 people visited it.

The geography of organizations concerned with rocket building and cosmonautics grew wider and wider. After studying theory, the enthusiasts moved to direct experiments.

In 1926-1927, there was a student circle in Kharkov under the aviation department of the Kharkov Technological Institute, and its members tried to develop a powder-propelled rocket engine for a flying aircraft model [13].

In 1928, the Section for Interplanetary Travel was founded in Leningrad, at the Institute of Railroad Engineers (presently the Leningrad Institute of Railroad Engineers imeni Academician V. N. Obraztsov), which was chaired by the dean of the institute's Air Travel Faculty, Prof N. A. Rynin (1877-1942). In 1928-1932, N. A. Rynin published a unique work (3 volumes, 9 editions) entitled "Interplanetary Travel," which was in essence the first encyclopedia on the history and theory of jet propulsion and spaceflights. Let us note that N. A. Rynin created one of the first centrifuges for animals in the USSR [14]. The research done by scientists of the Central Psychophysiological Laboratory under the leadership of N. M. Dobrotvorskiy in the 1920's [15] was very important to subsequent development of space medicine, in particular studies of G loads from linear and radial accelerations. The works of the outstanding popularizer Ya. I. Perel'man (1882-1942) and the well-known aerodynamic specialist and scientist, V. P. Vetchinkin, as well as others, played a considerable role in disseminating ideas of jet propulsion and interplanetary travel.

Thus, the conditions were created in our country in 1917-1928 for development of practical work in the area of rocketry.

Second stage (1929-1933). This is when experimental work began and the main directions were formed for development of rocketry. Industrialization of our country, development of the material and technical base of socialism had a strong influence during this period on development of rocket building. Armed with the decisions of the 16th Congress, the Party deployed the offensive of socialism over the entire front [16]. By the early 1930's, the first scientific research and experimental design organizations were created in the USSR, and their fruitful endeavors marked the beginning of Soviet rocket building.

There was further development of work in the GDL [Gas Dynamics Laboratory], which became complex [combined]. There, studies and tests were made of solid-fuel, liquid-propellant and electric rocket engines. In 1928, in addition to N. I. Tikhomirov and V. A. Artem'yev, I. I. Kulagin (production of powder), D. A. Venttsel' and N. A. Upernikov (external rocket ballistics), G. V. Bogolyubov

(rocket control system), G. E. Langemak (powder ballistics) worked in this laboratory and, from 1929 so did B. S. Petropavlovskiy (construction of powder [solid-propellant] rockets) [17]. In the period from 1927 to 1933, solid-propellant take-off of light and heavy aircraft (U-1. TB-1 and others) was developed at the GDL; by the end of 1933, 9 types of rocket missiles using smokeless powder were developed and tested in launches on land, in the sea and air. Pilot S. I. Mukhin (1885-1934) was the first to fire rocket missiles from a U-1 aircraft in the air. On 15 May 1929, a department was founded in the GDL that was headed by the talented scientist and designer, V. P. Glushko (who subsequently became an academician, the title of Hero of Socialist Labor was bestowed upon him twice; was a recipient of the Lenin and State Prizes). Jet-propelled aircraft (RLA), the world's first electrothermal rocket engine (ERD) and the first Soviet liquid-propellant jet LRE engines were developed in this laboratory [18]. In 1930-1933, a series of experimental rocket motors was developed--ORM engines (from the ORM, ORM-1 to the ORM-52 with up to 300 kg thrust), as well as several experimental jet aircraft (RLA-1, RLA-2, RLA-3 and RLA-100). V. P. Glushko, founder of Soviet rocket engine building, trained excellent rocket-building personnel who subsequently developed, under his supervision, high-power rocket engines mounted on many Soviet rocket carriers [19]. The GDL changed into a large organization with a staff totaling about 250 people.

The opportunities for scientific research work by enthusiasts of rocketry and interplanetary flights broadened significantly when the proper organizations began to be founded within the framework of the USSR Osoaviakhim, whose activities were the object of constant attention on the part of the Party's Central Committee. Osoaviakhim not only conducted military patriotic work among the public, but cooperated in development of a number of new sectors. The central council of Osoaviakhim, which was elected at its first congress in January 1927, included prominent Party, state and military figures, such as P. I. Baranov, A. S. Bubnov, K. Ye. Voroshilov, O. O. Kamenev, V. V. Kuybyshev, M. N. Tukhachevskiy, I. S. Unshlikht, V. Ya. Chubar', R. P. Eydeman and others. The chairman of the USSR Sovnarkom was the first chairman of the central council and subsequently its honorary chairman [20].

From the very beginning, scientific research was among the most important functions of Osoaviakhim. In September 1931 [20], The Moscow group for the study of jet propulsion (GIRD) was founded within the office of aircraft engineering of the central council of Osoaviakhim, and it made a fundamental contribution to development of Soviet rockets using liquid fuel. F. A. Tsander was its first head. In 1932, Sergey Pavlovich Korolev was appointed head of GIRD; he subsequently became the founder of practical cosmonautics, chief designer of space rocket systems, an academician and twice awarded the title of Hero of Socialist Labor.

The outstanding aerodynamic specialist, V. P. Vetchinkin, gifted engineers and designers M. K. Tikhonravov, Yu. A. Pobedonostsev, Ye. S. Shchetinkov, L. S. Dushkin, I. A. Merkulov, M. S. Kisenko, A. I. Polyarnyy, Ye. K. Moshkin and others collaborated in the GIRD.

In 1932, with the support of the central council of Osoaviakhim and M. N. Tukhachevskiy, armaments chief of the Workers' and Peasants' Red Army, the GIRD gradually changed from a public organization into a government one. There

was formation of a scientific research and experimental design enterprise with its own staff and base, financed both by funds of Osoaviakhim and government funds. Immeidately after organization of scientific production departments, a Party group was formed at the GIRD headed by L. K. Korneyev, a Party member and Party group organizer from 1918 [20].

Organizationally, the Party group was part of the RKP(b) Party cell of Osoaviakhim, which enabled the communists of GIRD to operationally resolve their production problems over Party channels.

The GIRD communists participated actively in propagandizing and popularizing rocketry. The First All-Union Conference of Socialist Industrial Workers, which was convened in January 1931 at the initiation of the Central Committee of the Party, played an important part in mastering the technology. The slogan advanced by the Party, "Bolsheviks must master technology," became the center of attention of all Party, trade-union, business and Komsomol organizations. The press began to implement a broad program ot organizing industrial and technological propaganda. Scientific engineering journals appeared--TEKHNICHESKAYA PROPAGANDA [Engineering Propaganda] and TEKHNIKA MOLODEZHI [Engineering for Young People], as well as the newspaper, TEKHNIKA [Engineering or Technology], which reported on the new engineering advances in the USSR and abroad [21]. The importance of broad deployment of scientific and technical propaganda was also noted at the 17th Party Conference, which convened in January-February 1932. GIRD members made use of various forms of verbal propaganda; they regularly published articles in the periodic press and organized courses for GIRD propagandists. In time, there was a considerable increase in volume of tasks performed by GIRD, and by the start of 1933, the Workers' and Peasants' VKP(b) [All-Union Communist Party (of bolsheviks)] of Baumanskiy created an independent Party cell. By this time, there were already about 60 people working in the GIRD, including 12 communists. The Party organization played a major role in uniting the group and solving a number of important and responsible problems. GIRD was actively involved in rocket and engine development. On 17 August 1933, the first Soviet liquid-propelled "09" rocket was launched. Mikhail Klavdiyevich Tikhonravov was the designer of this rocket and the rocket engine for it, which operated on liquid oxygen and congealed [gelatinous] gasoline. On 25 November 1933, the GIRD-Kh rocket with a "10" engine was launched. By this time, plans for several other liquid-propelled ballistic and winged missiles had been worked out.

In addition to scientific engineering problems, the Moscow GIRD, which was named the central GIRD, performed considerable public work. In accordance with the decision of the central council of Osoaviakhim, it coordinated and rendered methodological and organizational assistance to GIRD's founded in other cities of the country.

Concurrently with the Moscow GIRD, the Leningrad GIRD (LenGIRD), which was founded in November 1931, also worked well. The main members of this group were V. V. Razumov (chairman of LenGIRD and head of the planning and designing group), Ya. I. Perel'man (deputy chairman and head of the scientific propaganda group), N. A. Rynin, I. N. Samarin, A. N. Shtern, Ye. Ye. Chertovskoy (deputy chairman of the Leningrad Osoaviakhim) [22].

The Party's Central Committee and Party organizations were persistent in obtaining good planning in organization of research work, in accordance with the tasks and prospects of aviation and rocketry; they were concerned about the results of scientific research, they helped eliminate duplication in research and design work, and they cooperated in publishing scientific works.

The work done by the GDL and GIRD played an enormous part in establishing the Soviet school of rocket building. Further progress in development of rocket technology made it necessary to expand research and experimental design work, and raised the question of establishing a single research center. In 1932-1933, prominent Party and State figures--M. N. Tukhachevskiy, K. Ye. Voroshilov, G. K. Ordzhonikidze, N. V. Kuybyshev and others--were involved in organizing such a research center.

Third stage (1934-1938). During this period there was development of a broad program of experimental work in all of the main directions of rocketry. There was a movement for mastering new technology in all sectors of the economy, on the basis of the decisions of the 17th Party Congress. The slogan, "Cadres solve everything!" was coined to solve the problem of personnel capable of learning and making full use of technology. The Party's policy and situation in the country created conditions for further deployment of theoretical and practical work in the area of rocketry. On 21 September 1933, the world's first Scientific Research Institute of Jet Propulsion (RNII) was organized in Moscow, on the basis of the GDL and GIRD. The alliance at RNII of prominent specialists, theoreticians and practitioners in the area of jet propulsion and rocket building was instrumental in laying a solid and reliable scientific foundation, on the basis of which jet-propelled aviation, rocketry and space research began to develop rapidly in our country. I. T. Kleymenov, former head of GDL, was appointed chief of this institute and S. P. Korolev, former head of GIRD, was appointed deputy chief in science, a post that was held by G. E. Langemak from January 1934. S. P. Korolev headed the department of winged rockets. The institute staff kept in close touch with K. E. Tsiolkovskiy; they elected him honorary member of their technical council. A new stage began in development of Soviet rocket building. The RNII dealt with all of the main problems of rocketry.

Together with the TsAGI and other institutions, this institute tackled important theoretical and practical problems of rocketry [23]. Within the walls of the institute, several new experimental ballistic, winged missiles and engines for them were developed. The development of liquid-propellant rocket engines and liquid-propellant rockets constituted the main task, on which attention was concentrated [24].

Soon after the establishment of the RNII, the jet-propulsion group of the Military Scientific Committee (VNK) assumed the job of coordinating the work of societies and groups of rocketry enthusiasts, and after it this job was taken over by the Stratosphere Committee under the central council of Osoaviakhim.

Already in the early 1930's, the USSR Academy of Sciences began to be interested in work dealing with rocketry. In April 1934, the First All-Union Conference

on the Study of the Stratosphere convened in Leningrad [25], and its participants included all major figures of Soviet science, scientists and engineers concerned with problems of rocketry. Two rockets using liquid fuel were described in papers delivered by Prof N. A. Rynin and engineer M. K. Tikhonravov. S. P. Korolev delivered an interesting paper on the topic of "Flights of Jet-Propelled Craft in the Stratosphere."

In March 1935, the First All-Union Conference on Use of Jet-Propelled Aircraft to Explore the Stratosphere convened in Moscow. At this conference, there was discussion of concrete questions of development of rockets and rocket aircraft. V. P. Glushko expounded some important ideas on the design of liquid-propellant rocket engines in his paper, "Liquid Fuel for Rocket Engines and Specifications for Rocket and Engine Materials." S. P. Korolev delivered a paper entitled "Manned Winged Rocket," ending it w.ch the following words: "The Task for the future is to master the fundamentals of rocketry and be the first to reach stratospheric and ionospheric altitudes through persistent daily work, without excessive noise and publicity that are, unfortunately, so often still inherent in many works in this area" [26]. Much was done before 1941 to achieve this. Refinement of hydraulic ["gidrovskiye"?] rockets continued at the RNII: 09(13), 07, 05 and 06 using liquid fuel, and the RLA-2 vertically launched rocket built at GDL [27].

In 1934-1938, a series of guided winged missiles was constructed at the RNII under the leadership of S. P. Korolev: 212, 201, 216, 217 and others. The type 212 rockets with ORM-65 engines designed by V. P. Glushko were submitted to flight tests in 1939. A series of experimental liquid-propellant rocket engines, using nitric acid as oxidants (from ORM-53 to ORM-70) and tetranitro-.hane (from ORM-100 to ORM-102) and others were developed in 1934-1938 under the supervision of V. P. Glushko.

The ORM-65 engine designed by V. P. Glushko, which underwent official testing in 1936, was the best engine of that time.

In 1937-1938, ground tests were made of the RP-318 rocket aircraft designed by S. P. Korolev with liquid-propellant engine ORM-65. An important achievement at the third stage was definition of optimum directions of development of rocketry, and this was related primarily to the establishment and work of the RNII. It should be noted that, in the 1930's (although this topic requires special consideration), V. V. Strel'tsov, A. P. Appolonov, G. Ye. Vladimirov, P. I. Yegorov, L. A. Orbeli and other researchers conducted work that subsequently was important to development of space biology and medicine [28, 29].

Fourth stage (1939-1945). At this stage, prototypes of Soviet rocketry were developed for practical use. The increased danger of war required that the Central Committee of the Party and Soviet government make some important decisions on military-economic issues and much organizational work. At the 18th Party Congress (March 1939), there was elaboration of an economic program for development of our country for the current 5-year period. There was further development of the defense industry, aviation and rocket building. The 604 ballistic missile, which was developed at the RNII in 1939, flew for a distance of up to 20 km. On 28 February 1940, test pilot V. P. Fedorov made the first flight on the RP-318-1 rocket aircraft of S. P. Korolev using a

liquid-propellant engine. The rocket aircraft of S. P. Korolev became the precursor of Soviet jet-propelled aviation. During the difficult period of war, on 15 May 1942, test pilot G. Ya. Bakhchivandzhi made a flight on the first Soviet BI-1 jet aircraft developed by A. Ya. Bereznyak and A. M. Isayev in the design office of chief designer V. F. Bolkhovitinov. A liquid-propellant jet engine with 1110 kgf thrust, which was designed at the RNII, was installed on this aircraft.

In 1942-1943, several flights were made on the BI-1 at speeds of up to 800 km/h. The BI-1 flights heralded the birth of Soviet jet aviation.

In May 1939, during the battles in the region of the Khalkhin-Gol River, the Japanese invaders experienced the effects of the RS-82 rockets [projectiles] developed by the RNII team. During the years of the Great Patriotic War, the legendary attack planes [bombers] of S. V. Il'yushin, armed with RS-82 and RS-132 [rockets] were named "black death" by the Hitlerites. These missiles were also installed on the fighter planes of S. A. Lavochkin and A. S. Yakovlev.

At the start of the Great Patriotic War, as the result of efforts made by a large group of specialists, the BM-13 rocket device, affectionately named "Katyusha" by the public, was designed and constructed at the RNII. The first salvo from the Katyushas was fired by the battery of Captain I. A. Flerov along the Fascist-occupied railroad junction of Orsha on 14 July 1941. This high-power weapon played a large part in the Great Patriotic War.

Design, construction and installation of control systems on rockets, as well as flight tests, occupied a special place in the work of the RNII. For example, automatic gyroscopes were developed at the RNII for types 201, 212, 216 and 609 rockets, which made it possible to refine the automatic launching of rockets from a launching ["ejection"] trolley and assure stable flight thereof at the first stage of the ascent trajectory.

Soviet engineers and designers worked fruitfully on development of ramjet engines (PVRD). On 19 May 1939, the world's first rocket with a PVRD at the second stage of design by I. A. Merkulov was launched from the range near Moscow.

In 1941, an experimental design office for liquid-propellant rocket engines was created, which developed the family of auxiliary liquid-propellant rocket engines (from RD-1 to RD-3), which underwent ground and flight tests in 1943-1946 on aircraft designed by V. M. Petlyakov, S. A. Lavochkin, A. S. Yakovlev and O. O. Sukhoy. Engine starting was completely automatic and there was no limit on number of starts.

Thus, thanks to the constant concern of the Party and government, many sectors of science and engineering were created in the USSR, without the development of which the inception of cosmonautics would have been impossible. The Party and government supported in every way the endeavors of experimental design organizations, such as GDL, GIRD and the RNII, which made a fundamental contribution to development of Soviet rocket science and technology. Remarkable cadres of rocket builders grew up in these organizations, and they made their contribution to the cause of shattering fascism. Many of them became prominent scientists and participated in development of the first space rocket systems.

The experience gained through the work of the GDL, GIRD and RNII was instrumental in further development of groups involved in Soviet rocket building and cosmonautics, which were headed by S. P. Korolev, V. P. Glushko, M. K. Yangel', A. I. Isayev and other Soviet designers [30, 31].

The achievements of Soviet science and technology in the areas of aviation and rocket building constituted the foundation, on the basis of which there was unprecedented development of Soviet rocketry and cosmonautics after the Great Patriotic War.

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EXPERIMENTAL AND GENERAL THEORETICAL RESEARCH

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PHYSIOLOGICAL AND HYGIENIC ASPECTS OF IMPLEMENTATION OF COSMONAUTS' WORK IN ORBITAL FLIGHT

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[Article by I. P. Abramov, A. S. Barer, M. I. Vakar, L. G. Golovkin, V. P. Zinchenko, S. N. Filipenkov, R. Kh. Sharipov and V. V. Shchigolev]

[English abstract from source] This paper briefly describes physiologo-hygienic evaluations of space suits, data of the pre-flight training and extravehicular activities of the Salyut-6 crew members. It discusses changes in physiological parameters, energy expenditures, heat release and associated performance of the autonomic life support system. The paper also analyzes physiologo-hygienic aspects of the extravehicular activity of the Salyut-6 crew members.

[Text] Use of a new semi-rigid type space suit with a self-contained life-support system (SLSS) was the distinction of extravehicular activity from the Salyut-6 station. For the first time in Soviet practice, a water-cooled suit (WCS) was used, which maintained heat balance of cosmonauts at virtually any level of physical activity. The absolute pressure in the space suit of the Salyut-6 station was held at 270-300 mm Hg in the main working mode, and there were provisions for lowering it to 198-210 mm Hg in the mode of short-term work. The first pressure mode is intended for scheduled operations in open space. Safety of decompression from earth's atmosphere was assured by 25-30-min denitrogenization while breathing with oxygen at the stage of preparing for EVA. The second mode, with somewhat greater mobility of the space suit, is intended for handling emergency type tasks. Brief use of this mode is attributable to the fact that the probability of caisson's disease appears when one is exposed to such pressure for any length of time.

The operating stage was preceded by physiological, hygienic and ergonomic evaluation of space suite systems operation.

First, let us discuss the results of pressure chamber tests. After sealing the space suit and changing the gas environment, the atmosphere in it was close to pure oxygen. Nitrogen content constituted a mean of no more than 8% (up to 23 mm Hg at the basic pressure mode and 17 mm Hg at low pressure mode). Partial oxygen tension constituted 250 to 280 mm Hg in the main

mode of the space suite and 170 to 200 mm Hg in the brief operating mode. Partial CO_2 pressure ranged from 6 to 15 mm Hg with body output of 0.3 to 2.4 ℓ/min CO_2 (STPD). The levels of toxic products of human vital functions and emissions from polymers were below the maximum permissible concentrations.

During the main period of SLSS operation, the microclimate was close to the comfortable level. Relative humidity of the gas atmosphere scaled to a temperature of 25°C constituted 30 to 60% with brief elevation to 70-90% when the heat exchanger of the SLSS was turned off. The temperature of the gas environment and fluid in the WCS ranged from 5 to 30°C, depending on level of heat production by the body. The method of adjusting water temperature in the WCS in accordance with subjective heat perception was rated as quite satisfactory. In the range of energy expenditure (EE) from 100 to 340 W, due to heat removal by the WCS it was possible to maintain the thermal state of the body in the range of comfortable warmth. Mean skin temperature (T_s) ranged from 29.8 to 35.6°C, rectal temperature (T_r) from 36.6 to 37.8°C, oral temperature (T_{or}) from 35.8 to 37.5°C and mean body temperature (TB) ranged from 35.8 to 36.8°C. The temperature measured in the parotid region (T_p) constituted 34.1-37.5°C. Total heat content of the body did not differ from the base level by more than 120 kJ. Average fluid loss constituted 17.1±4.3 g/kg body mass per hour. With simulated malfunction of water cooling and EE level of 210-290 W, the ventilation system maintained the thermal state within the permissible range for the time required to return to the station.

Virtually the entire range of operations related to extravehicular activity on the surface of the station had been worked out for immersion-caused weightlessness and flights in aircraft over a Keplerian trajectory. According to the subjects accounts, all of the operations listed in the program could be performed. The principal physical load was on the hand [or arm] muscles. In order to augment mobility of the hands, in the pressure shell , pressure collars [bearings] were used in the region of the shoulder and wrist, in addition to the soft articulation at the elbow. Because of the smaller load on the feet, only soft articulations [joints] were used on the leg shells in the hip, knee and ankle regions of the shell. Ergonomic evaluation of the space suit revealed that it was convenient to put on, sufficiently flexible, fingers had good tactile sensibility in performing fine operations in individual pressure gloves, performance of operations with suit controls was highly reliable, audiovisual monitoring of systems was feasible, optic characteristics of glass parts and density of the light filter were adequate. The range of adjustment of the size of the space suit took into consideration not only the differences in base anthropometry, but cosmonauts' "growing" in the course of flying under weightless conditions. It was confirmed that the same space suite could be used by cosmonauts with different anthropometric parameters, and only appropriate adjustment of the length of the soft shells of the limbs was required.

Energy consumption [capacity] of the main operations and simulated emergency situations, as well as changes in several physiological parameters when testing space suits, are listed in Table 1. During scheduled activity of operators, physiological functions such as pulse rate (PR) and respiratory rate (RR) were determined by the level of physical activity and they were directly related to the EE level. PR and RR were somewhat higher during operations that caused emotional tension or overheating.

Table 1. Mean values and range of changes in physiological parameters checked at rest (R), during performance of light (L), average (A), heavy (H) physical work and simulation of different operations in an altitude [thermal vacuum] chamber

No	OPERATION	EE, W	PR	RR	T_{OR}	T_P
			PER MINUTE		°C	
1	SYSTEMS CHECK (R)	100±30	78 (55—84)	16 (6—24)	36,6—37,0	34,1—36,6
2	CONTROL OF SPACE SUIT SYSTEMS (L)	180±40	96 (72—100)	18 (10—25)	36,6—37,0	34,1—36,6
3	CHANGING PRESSURE AND SWITCHING ON ADDITIONAL OXYGEN DELIVERY INTO SPACE SUIT (L)	210±40	91 (80—129)	20 (18—24)	36,6—37,0	34,8—36,7
4	CONNECTING (DISCONNECTING) ELECTRIC CABLE (L-A)	280±70	98 (90—120)	23 (15—30)	36,6—37,0	34,8—36,7
5	CONNECTING PNEUMOHYDROSYSTEMS OF SPACE SUIT (A)	350±70	106 (100—142)	24 (20—30)	36,6—37,1	35,0—36,8
6	"INSURANCE" (L-A)	TO 350	63—100	18—27	36,8—37,1	35,0—36,8
7	EXIT AND MOVEMENT OVER SPACECRAFT SURFACE (A-H)	460±40	102 (84—136)	25 (21—34)	36,8—37,0	35,7—37,0
8	RETURN AND MOVEMENT OVER SPACECRAFT SURFACE (A-H)	490±70	108 (88—147)	27 (20—36)	36,8—37,0	35,7—37,0
9	TRANSPORTING ADDITIONAL 150 KG (H)	600±50	133 (108—165)	31 (26—34)	37,2—37,5	36,0—37,3
10	MAXIMUM LOAD (H)	800±40	145 (120—167)	33 (27—42)	37,3—37,5	До 37,5
11	SIMULATED MALFUNCTION OF WATER COOLING AND BODY OVERHEATING (A)	250±40	130 (121—138)	25 (20—30)	37,5—38,0	>37,5
12	MISTAKES IN WORKING WITH SPACESUIT CONTROLS (L)	180±40	110 (92—130)	18 (12—24)	36,6—37,0	34,1—36,6
13	SYSTEM MALFUNCTION (EMOTIONAL STRESS)	210±70	178 (164—192)	30 (25—36)	36,6—37,0	34,1—36,6

Table 2.
Some findings of medical examination of crews prior to EVA operation

CREW MEMBER	AT REST			PHYSICAL LOAD (M-10-3 TEST)		
	TB, °C	AP, MM HG	PR/MIN	RR /MIN	PR /MIN	AP, MM HG
CDR-1	36,5	115/85	63—70	15	126	153/78
FLE-1	36,1	115/60	58—73	15	108	139/65
CDR-2	36,6	120/75	74—82	18	135	134/61
FLE-2	36,5	115/70	65	12	112	138/60
CDR-3	36,1	115/75	60—69	20	124	
FLE-3	36,8	110/70	61—76	16	92	

The cosmonauts underwent special training to acquire skill in working with space suit systems and refine operations related to extravehicular activity [EVA]. We used altitude [thermal pressure] chambers, "hydroweightlessness" stand and a flying laboratory. During training, all of the cosmonauts were submitted to 4 to 6 ascents in the pressure chamber with prebreathing for 25-30 min at a pressure of 550 mm Hg followed by 2-4 hours of work with average EE of 240 to 350 W, the absolute pressure in the space suit ranging from 270 to 300 mm Hg, with change to absolute pressure of 198-210 mm Hg for 15 min. We failed to observe any symptoms of caisson's disease.

Table 3. Energy expenditure/heat removal (in W) during period of preparation for and EVA

CREW MEMBER	OVERALL MJ	AIRLOCKING BEFORE EXIT	EXIT	AIRLOCKING AFTER EXIT	CHECKING SYSTEMS			OPENING (CLOSING) HATCH	EQUIPMENT ASSEMBLY (DISASSEMBLY)	MOVING ON STATION SURFACE	TELEMETRIC REPORTING AND PHOTOGRAPHY
					AIRLOCK	SPACE SUIT	WHEN INSPECTING STATION				
CDR-1	3,8 / 3,9	230 (140–280) / 230 (210–420)	300 (150–420) / 310 (280–590)	210 (140–310) / 190 (80–400)	170–280 / 210–390	140–160 / 70–210	280–380 / 350–380	350–430 / 410–590	—	—	280 / 310
FLE-1	2,7 / 2,9	170 (100–210) / 220 (210–300)	210 (100–410) / 170 (159–560)	190 (120–240) / 280 (70–450)	170–210 / 210–450	110–130 / 110–130	280–350 / 210	380–410 / 450–560	240–380 / 210–350	—	210 / 210
CDR-2	3,5 / 3,0	220 (140–420) / 210 (200–280)	270 (170–410) / 230 (140–490)	220 (140–240) / 210 (70–350)	140–350 / 70–350	140–170 / 70–140	210–280 / 140–210	350–410 / 310–490	240–380 / 170–490	—	280 / 210
FLE-2	5,0 / 3,8	270 (150–350) / 270 (170–280	350 (280–490) / 270 (120–490)	350 (140–420) / 260 (100–350)	280–420 / 110–350	150 / 140	230–350 / 120–240	400–450 / 340–490	280–490 / 170–420	350–420 / 140–180	310–350 / 140–200
CDR-3	2,4 / 1,8	190 (140–280) / 60 (40–170)	300 (230–520) / 280 (140–600)	140 (100–350) / 210 (130–240)	140–280 / 110–180	140–230 / 40–150	230–350 / 180–210	420–530 / 540–600	240–490 / 180–210	490 / 210	—
FLE-3	3,5 / 3,1	220 (140–380) / 70 (60–170)	350 (280–530) / 410 (150–700)	240 (170–450) / 300 (90–450)	140–380 / 140–410	140–280 / 60–160	280–470 / 160–290	410–590 / 630–700	460–520 / 380–660	470–520 / 400–650	—

Note: Levels of heat removal in water and ventilation cooling circuit are given without consideration of heat flow through space suit shell.

The medical monitoring system developed for the space suit made it possible to record the pneumogram, EKG (DS lead), and monitor such physiological parameters as PR, RR and TB. Initially, we measured T_{or} and subsequently, in order to have continuous evaluation of thermal state and convenience of work, a system of measuring T_p was developed and adopted. In addition, during EVA, we used the cosmonauts' reports about their well being and SLSS parameters directly related to vital functions: pressure in space suit, oxygen uptake (according to pressure drop in oxygen tanks), CO_2 concentration in ventilated gas, water temperature at input of WCS (T_{WCS}), difference in water temperature at output and input of the WCS. From these data and with consideration of the results of ground-based tests, determination was made of EE and heat removal (Q), and mutual conformity thereof was evaluated. In view of the assumptions made in the calculations, as well as limitations with regard to accuracy of readings and transmission of information, relative margin of error in values of EE and Q constituted up to 20%.

During EVA, all medical and technical parameters were monitored and, if they exceeded the permissible range, there were several recommendations aimed at assuring the safety of cosmonauts and performance of their assignment (turning on reserve and back-up systems, changing level of physical activity, heat regulation, etc.). In addition, a set of measures was worked out for rendering first aid if health worsened or complaints of feeling poorly were made.

To date, three EVA's have been made from the Salyut-6 station (on 20 December 1977, 29 July 1978 and 15 August 1979).

The crew's initial state 3-4 days prior to EVA was rated as quite satisfactory in all cases. The obtained data (Table 2), with consideration of dynamics of psychological status and absence of complaints, made it possible to draw the medical conclusion that the cosmonauts were ready to perform the work program.

Tables 3 and 4 list data about each of the cosmonauts during EVA.* Some of the telemetry parameters and typical dynamics of changes in EE, Q and TB for CDR-3 and FLE-3 during the period of EVA out of the Salyut-6 station are illustrated in the Figure.

Just before the EVA, at the airlock stage, average hourly EE for most cosmonauts constituted 170-230 W and reached the maximum of 270 W in FLE-2 when preparing for EVA. At this stage, the most labor-consuming operations were the final ones when changing from onboard life-support systems to the ALSS of the space suit, when EE of all cosmonauts increased to 280-420 W. The physiological parameters were consistent with the work performed and they changed over the following ranges during the airlock period: PR 60 to 130/min, RR 10 to 30/min.

During the first two EVA's, Q conformed to the level of physical activity when working from onboard systems, and it constituted 210-270 W, which provided for a thermally neutral state of the cosmonauts by the end of the airlock period. Medical monitoring shows that T_{or} was 36.7°C for CDR-1 and FLE-1, 36.1°C for CDR-2 and 36.6°C for FLE-2. It must be noted that the observed brief decline of T_{WCS} to 15-17°C during the airlock period was associated with

*CDR--commander, FLE--flight engineer; the numbers refer to the numbers of the main missions aboard the Salyut-6 station.

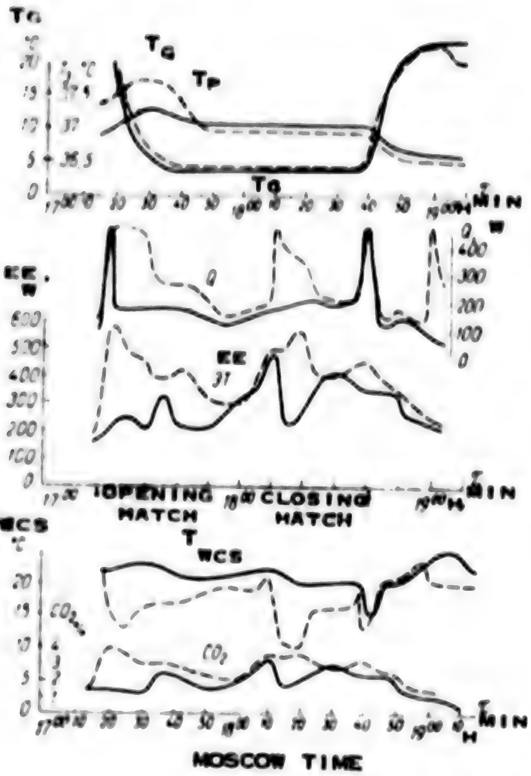
local sensations of overcooling of the feet of FLE-1 and generalized overcooling in FLE-2. Subsequent elevation of T_{WCS} to 18-24°C normalized heat sensations.

Table 4. Individual changes in PR/RR (per min) as a function of EE (in W) during training in heat-pressure chamber (HPC) and during EVA

CREW MEMBER		EE RANGE						
		70–110	111–210	211–280	281–350	351–420	421–490	491–560
CDR-1:	HPC	72–96 / 8–15	72–108 / 12–16	78–100 / 12–18	96–112 / 12–20	96–120 / 16–24	110–138 / 14–25	127–152 / 20–25
	EVA	74–84 / 12–16	80–86 / 15–20	88–100 / 16–24	100–114 / 26–30	114 / 30		
FLE-1:	HPC	56–72 / 6–15	65–74 / 8–16	78–90 / 10–18	80–98 / 12–21	89–100 / 12–24	94–102 / 12–22	104 / 24
	EVA	72–78 / 12–16	78–84 / 16–24	90–94 / 22–30				
CDR-2:	HPC	64–82 / 8–12	82–88 / 8–22	84–92 / 14–26	78–100 / 22–28	82–110 / 22–30	102–115 / 24–33	120–134 / 28–32
	EVA	63–80 / 14–20	72–90 / 14–24	102–109 / 24–26	102–110 / 24–30	104–156 / 26–34		
FLE-2:	HPC	58–84 / 12–20	74–88 / 12–22	82–100 / 12–22	86–102 / 18–24	88–108 / 20–24	94–118 / 18–28	114–120 / 25–28
	EVA	60–76 / 16	80 / 16	84–108 / 18–24	95–110 / 20–22	110 / 22	130–140 / 24–26	
CDR-3:	HPC	50–74 / 6–18	74–96 / 8–26	80–102 / 22–31	108 / 34	92–120 / 26–34	118–120 / 32–35	127 / 38
	EVA	70–72 / 14–18	76–90 / 15–20	90–110 / 18–23				
FLE-3:	HPC	48–70 / 14–20	66–84 / 18–24	70–88 / 15–25	80–91 / 22–25	90–96 / 21–27	96–110 / 24–30	98–102 / 30
	EVA	66–70 / 10–18	68–82 / 14–20	78–80 / 14–22	100 / 20–22	108 / 21–25	130 / 25	150 / 36

During the third EVA, toward the end of the airlock period T_{WCS} rose from 20 to 31°C for technical reasons, while mean Q level did not exceed 70 W. During performance of physical work, this lead to some overheating of the body and elevation of T_p from 36.1 to 37.0°C in CDR-3 and from 36.3 to 37.4°C in FLE-3. On the whole, during the airlock period the condition of the cosmonauts was rated as quite satisfactory; all monitored physiological parameters did not exceed permissible values and they felt well. On the basis of the results of analysis of space suit system operation and medical monitoring data during the airlock period and prebreathing, it was decided in all cases that it was possible to conduct the EVA.

During the period of EVA during all three missions, the SLSS operated in the nominal mode and provided for normal conditions of vital functions. Pressure in the space suits was maintained at 270 to 300 mm Hg. After changing the



Dynamics of some physiological and technical parameters during EVA on 15 August 1979

Solid line--change in parameters of CDR-3 during work, dotted line--same changes in FLE-3.

T_g) temperature of ventilating gas at output from heat exchanger

CO_2) CO_2 content in ventilating gas

gas atmosphere during airlocking, the atmosphere was close to a pure oxygen. CO_2 content did not exceed 13 mm Hg. The differences found in several technical and physiological parameters during this period were determined by the nature and volume of operations performed. The first EVA, during which the CDR-1 helped FLE-1 in moving about and keeping still while checking the docking module, was characterized by higher EE, Q and PR expressly in the CDR-1. Since all of the operations were performed manually, CDR-1 could not adjust the T_{WCS}, which remained virtually unchanged throughout the EVA period. During the second and third EVA's, FLE-2 and FLE-3 performed a large volume of work related to high levels of EE and, accordingly, Q, whereas CDR-2 and CDR-3 provided only supervision, so-called insurance, observation of the work. The monitored physiological parameters changed over the following ranges during the EVA period: PR from 72 to 156/min, PR [sic] from 12 to 36/min, T_p from 37.0 to 37.7°C. Comparison of PR and RR to levels demonstrated on the ground while cosmonauts performed work varying in EE wearing the space suits revealed that they were similar in CDR-1, FLE-1 and CDR-3 to those obtained in ground-based training, whereas the levels were somewhat higher in CDR-2, FLE-2 and FLE-3.

At the first stage of work in space, the most labor-consuming operations were performed: opening the hatch, installing and replacing equipment on the outer surface of the station, preparing the locking [fixation] system. EE then increased to 420-600 W, which was the absolute maximum for the entire period of EVA. Mean hourly EE when working on the outer surface of Salyut-6 changed as a function of the EVA program, from 270 to 300 W for the CDR; it was minimal (210 W) in the FLE-1 and constituted about 350 W for FLE-2 and FLE-3. The mean Q level corresponded to the mean hourly EE, ranging from 180 to 410 W (see Table 4). The heat-regulating system of the space suit provided for a relatively comfortable heat status of the cosmonauts, there being brief local sensations of overcooling or overheating. The choice of the necessary Q level was made by the cosmonauts during the first 10-30 min of work by means of altering T_{WCS} 1-3 times. Q exceeded the EE level for several minutes after turning on the SLSS in CDR-1, FLE-1 and FLE-2 due to drop of T_{WCS} to 4-6°C. As we have already noted, readjustment [overadjustment] of Q was associated with the sensation of overcooling of the feet in FLE-1 and the back in FLE-2. In

contrast, during the period when Q constituted 500-700 W and exceeded significantly the current EE, FLE-3 was entirely satisfied with the operation of the heat-regulating system. He selected a T_{WCS} of 13°C, which elicited a pleasant sensation of coolness against the background of elevated TB as a result of prior overheating during the airlock period. The high efficiency of Q provided by the SLSS made it possible to gradually normalize the cosmonaut's thermal state.

Subsequently, the cosmonauts adjusted T_{WCS} in accordance with the level of physical activity. For moderate work, TWCS was set at 12 to 22°C, which corresponded to the average EE during the EVA period, according to the data obtained during ground-based training. When performing energy-consuming operations, the cosmonauts lowered the coolant temperature to 10-15°C, which caused a corresponding increase in Q.

Upon completing EVA, returning into the station at ambient temperature of 19-20°C and removal of space suits, CDR-1, FLE-1, CDR-2 and FLE-2 experienced generalized overcooling. This was apparently related to the difference between the microclimate of the space suit and station, the temperature and air humidity of the station being quite low, as well as dampness of underwear when working in the space suit. Changing into dry underwear and warm clothing, raising ambient temperature and intake of hot food led to normalization of heat sensations.

Thus, a space suit was successfully used on the Salyut-6 station, which provided both protection against the deleterious factors of space and normal work performance by cosmonauts during prolonged EVA. The reliable operation of the SLSS, adequate flexibility of the suit and proper level of training resulted in complete fulfilment of the program with the cosmonauts in good physical condition and feeling well. The monitored physiological parameters virtually failed to exceed the permissible ranges during the entire period of EVA.

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CHANGES IN VOLUME OF PLASMA, EXTRACELLULAR FLUID AND PLASMA PROTEIN MASS DURING ANTIORTHOSTATIC HYPOKINESIA AND IMMERSION

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[Article by A. M. Chayka and I. S. Balakhovskiy]

[English abstract from source] Twenty-four young volunteers were exposed to 30-56-hour head-down tilting (at -6° and -15°) in 5 experimental runs. The purpose of the study was to measure volumes of plasma and extracellular fluid, as well as concentrations of plasma proteins and hemoglobin. The results varied but in most cases the plasma volume decreased by 0.46-0.55 l, extracellular fluid volume by 0.75-2.15 l, and plasma proteins by 13.4-30.4 g. The hemoglobin concentration increased by 8-12% and that of plasma proteins in some cases grew and in others diminished. Water loading prevented the plasma volume decrease. The paper discusses with reference to the data in the literature the fate and role of plasma proteins in the regulation of the intravascular volume and fluid redistribution.

[Text] When man is immersed in water in horizontal position, or even merely stays in water in horizontal position for several days, there is considerable change in fluid-electrolyte metabolism, and such immersion could serve as a relatively simple and available model for the study of fluid-electrolyte equilibrium. The first publication offering an experimental explanation for the increased diuresis and natriuresis under such conditions appeared 30 years ago (in 1951) [1]. Interest in the question of regulating fluid-electrolyte metabolism under these conditions was initially prompted by the needs of clinical practice, the necessity of explaining the increased diuresis and natriuresis in cardiac patients after attacks of paroxysmal tachycardia, as well as of explaining fluid retention after commissurotomy in patients with stenosis of the left atrioventricular ostium. In the 1960's, interest in this question grew in connection with the possibility of simulating some effects of weightlessness experimentally using hypodynamia, as well as the need to investigate the mechanisms of impairment of fluid-electrolyte equilibrium under such conditions.

The changes that occured were explained [2, 3] on the basis of conceptions, according to which blood usually deposited in the lower limbs shifts to the large vessels of the chest, dilation of which causes stimulation of reflexogenic zones in the ostia of the venae cavae and in the left atrium, as a result of

which there is a reflex on the kidneys and increased elimination of fluid and electrolytes. This leads to reduction of intravascular volume and unloading of the reflexogenic zone.

The actual fact of increased diuresis during immersion in water, which was first observed by Bazett et al. in 1924 [4], as well as when changing from orthostatic to clinostatic position, has been confirmed many times. The existence of such a reflex is not questioned, although it is not always distinctly reproducible.

Gauer and later other researchers demonstrated in acute experiments with animals (direct electrophysiological observations) that the afferent arc of the reflex passes through the vagus [2, 5-7]. However, it is still not known whether the efferent arc passes through the sympathetic nervous chain [8-10], as Gauer initially believed, or whether it passes over a hormonal link, causing a decrease in secretion of antidiuretic hormone [11-3] and increase in natriuretic hormone secretion [14, 15].

While the above reasoning is not seriously disputed by anyone, and it can be taken as the foundation, there are some substantial "blank spots." In the first place, it is not clear which part of the fluid eliminated in urine originates from the vascular system (i.e., could really affect circulating blood volume) and which part originates from the extravascular sector. In the second place, if blood volume does indeed diminish, where do the proteins and erythrocytes it contains go?

In the desire to answer these questions and determine the exogenous circumstances upon which depends the amount of eliminated fluid, we conducted several series of studies with the participation of healthy young males, in whom we examined the fluid sectors of the body and mass of plasma proteins during 2-2.5-day antiorthostatic [head tilted down] hypokinesia and 7-day water immersion.

Methods

We conducted five series of studies at different times. Four subjects participated in the first series, and they spent 48 h in antiorthostatic position ($\angle\alpha = -6°$); in the second series, 5 men spent 30 h in antiorthostatic position under hypokinetic conditions ($\angle\alpha = -6°$), but unlike those who participated in the first series, they were on a diet with limited salt content.

In the third series, we used a 2% water load 24 h prior to 48-h antiorthostatic hypokinesia ($\angle\alpha = -6°$); they consumed all of the water within 30 min, which constituted 2% by volume of body weight.

In the fourth series there were 5 participants who spent 56 h in antiorthostatic position: $\angle\alpha = -15°$ in the daytime and $\angle\alpha = -6°$ at night.

In the fifth series of tests, 6 men spent 7 days in water, in horizontal position (water temperature 32-34°C), with the exception of night time, from 2200 to 1000 hours [sic], when they were in antiorthostatic position ($\angle\alpha = -6°$).

Fluid intake was not limited in any of the series of tests.

We measured circulating blood volume, extracellular fluid volume, total mass of plasma proteins, hemoglobin mass, sodium and urea excretion in urine and 24-h diuresis in all subjects.

Since it is known that blood plasma is a more labile system than erythrocytes and that injected labeled erythrocytes are mixed very rapidly and uniformly over the entire blood volume in healthy people [16], we expected that there would be no change in erythrocyte mass during bed rest and water immersion, for the first few days. In some of the tests (first and fifth series) this was confirmed by the direct measurement of hemoglobin mass before and after the test using the conventional laboratory carbon monoxide method* [17]. For this reason, we assessed change in blood volume on the basis of change in concentration of hemoglobin in peripheral blood, using the following formula for our calculations:

$$\Delta CBV = \frac{M_{Hb}}{C_{Hb}} - \frac{M_{Hb}}{C'_{Hb}} = \frac{[g]}{[g/\ell]} - \frac{[g]}{[g/\ell]} = [\ell]$$

where CBV is circulating blood volume, M_{Hb} is hemoglobin mass, C_{Hb} and C'_{Hb} are hemoglobin concentration in blood before the test and at the end of the study.

Extracellular fluid volume was determined directly according to dilution in the body of nonradioactive (pharmacopeic) bromide [18]. The change in total mass of plasma proteins was determined by calculation according to protein concentration in plasma, change in circulating blood volume and hematocrit, using the following formula:

$$PPM = 0.87 \cdot C_{pp} \cdot CBV\ (1-Ht) = [g]$$

where PPM is total mass of circulating plasma protein, C_{pp} is concentration of protein in plasma and Ht is capillary blood hematocrit.

Results and Discussion

As can be seen in the Table, in most series of tests the subjects showed a decrease in circulating blood volume, which was associated with an increase in diuresis and natriuresis. Thus, the main theses, upon which the Henry-Gauer conception is based, were confirmed. However, the decrease in intravascular volume, which we observed during antiorthostatic hypokinesia, exceeded somewhat the analogous loss observed at the same stages during horizontal hypokinesia [19]. Thus, while extravascular fluid loss in 48 and 56 h of antiorthostatic hypokinesia (series 1 and 4) constituted 0.54±0.05 and 0.55±0.11 ℓ, respectively (see Table), during horizontal hypokinesia it constituted only 0.42 ℓ according to [19].

In addition to the decrease in plasma volume under antiorthostatic conditions, there was a decrease in volume of extracellular fluid, which exceeded by 2-3 times the plasma loss. Loss of extracellular fluid in 2 days of antiorthostatic hypokinesia constituted a mean of somewhat over 2 ℓ, ranging in some cases from 1 to 3 ℓ (series 1). However, it is not possible to draw a comparison of our data on extracellular fluid loss to data in the literature. It should be

*R. K. Kiselev determined hemoglobin mass.

noted that there are differences in degree of decrease in intravascular and extracellular volumes in all series of tests with antiorthostatic hypokinesia. For example, following prehydration (third series), hypokinesia led to significant increase in diuresis and decrease in volume of extracellular fluid, but had little effect on hemoglobin concentration in peripheral blood (there was even some increase in plasma volume), i.e., dehydration was exclusively extravascular. Just like in this series of tests, some subjects who participated in the other series also failed to demonstrate any reliable decrease in plasma volume. However, in all series, the loss of extracellular fluid was several times greater than the decrease in intravascular volume. The decrease in blood plasma volume under hypokinetic and immersion conditions was also associated with a decrease in total mass of circulating plasma proteins. In the vast majority of cases, the "loss" of plasma protein constituted 25-35 g, which corresponds approximately to the plasma volume by which the intravascular volume diminishes. The only exception was the first series of tests, in which substantial loss of plasma was not associated with appreciable decrease in circulating protein mass. However, it should be noted that dehydration of the body was the most marked in expressly this series, due to reduction of extracellular fluid volume.

Changes in volume of circulating blood, extracellular fluid and plasma protein mass in man during antiorthostatic hypokinesia and immersion in water

SERIES	NUMBER OF CASES	CHANGE IN CONCENTRATION (% OF BASE VALUE)		CHANGES IN CIRCULATING BLOOD VOLUME, ℓ	LOSS OF PLASMA PROTEIN, G	LOSS OF EXTRACELLULAR FLUID, ℓ
		PLASMA PROTEIN	BLOOD HB			
I	4	+20%	+12%	−0,54±0,05	−1,4±1,9	−2,15±0,33
II	5	+5%	+8%	−0,46±0,04	−23,0±4,0	—
III	4	−9%	−4%	+0,20±0,04	−13,4±6,2	−0.75±0,00
IV	5	0	+9%	−0,55±0,11	−28,0±10,5	−1.43±0,5
V	6	−1,5%	+4%	−0,46±0,11	30,4±8,9	—

Many authors have studied the effect of hypokinesia and immersion on circulating blood and extracellular fluid volume [4, 19, 20]. However, in the literature available to us we did not ehcounter any data pertaining to studies of these parameters on a dynamic basis or comparative analysis thereof. Analysis of the available literature shows that the differences between results coincide approximately with our findings: in some cases loss of extracellular fluid corresponded approximately to the decrease in plasma volume (which, as we know, is referable to extracellular fluids) and in others it exceeded the latter by 3-4 times.

Thus, there is indeed output of fluid during hypokinesia and water immersion, but it involves the intercellular sector much more than blood plasma. With increased hydration of the body circulating blood volume many not decrease, since all fluid is dumped from the interstitial space or cells (third series).

The obtained data enable us to take a different view of the data gathered by Henry and Gauer about regulation of blood volume by means of discharge of its

liquid part in urine. Indeed, we see that the volume of the intercellular space is 10-12 times greater than of blood plasma. At the same time, it can change from the seemingly most insignificant factors and, in a number of cases, physiologically undetectable ones by 1-2 ℓ, i.e., to an extent that is known to exceed the volume of plasma that is dumped in the different test variants. This raises the question of the physiological meaning of unloading the vascular system by means of irreversible elimination of fluid and electrolytes in urine, when it would have seemed simpler to deposit this 0.5-0.7 ℓ of physiological solution in the intercellular space, which is considerably less than its ordinary physiological fluctuations. Another question that we cannot answer proceeding from the conception of Henry and Gauer is why does a considerable part of the fluid discharged in urine and, in a number of cases, most such fluid originate from intercellular space, rather than blood plasma, as is the case in studies using preliminary hydration, and what is the physiological mechanism that causes it to be eliminated?

Much attention is devoted in the literature to the question of regulation of intravascular volume under hypokinetic and immersion conditions, mechanisms of redistribution of fluid in vascular and interstitial volumes. Most authors tend to consider processes of fluid redistribution in intravascular and interstitial spaces to be dependent exclusively on the tonus of the sympathetic nervous system, ultimately the tonus of precapillary and postcapillary sphincters, which is probably important [21, 22].

However, proper attention is not given to the role of plasma proteins in this conception of the mechanism of fluid redistribution in intravascular and interstitial spaces. Yet it is a known fact that expressly plasma proteins, which create a certain level of oncotic blood pressure, perform a substantial part in maintaining stability of plasma volume. In this regard, it is also interesting to examine the question of the fate of plasma proteins from the volume by which intravascular fluid diminishes.

If, for example, the amount of plasma diminishes in a test by 0.5 ℓ with 75 g/ℓ protein content in it, the protein it contains constitutes 32.5 g; when it breaks down, 11 g urea should be formed, i.e., an amount that could not remain unnoticed when examining the nitrogen balance. In some experiments, this is expressly the extent of change in plasma protein mass, which constituted 1/6th-1/5th and, in some cases, 1/4th of the plasma protein pool (see Table). It should also be noted that the plasma protein concentration did not fluctuate significantly enough to appreciable alter oncotic pressure in plasma.

In some of the tests (4th series), plasma protein mass was also studied in the postexperimental period, i.e., recovery thereof was studied. It was found that there was relatively rapid restoration of the plasma protein pool following short-term hypokinesia. Thus, while plasma loss constituted about 30 g (-28.0±10.5) in 56 h of antiorthostatic hypokinesia , 24 h after hypokinesia the protein "shortage" only constituted half the loss during hypokinesia (-12.8±4.7 g). In some cases, when there was appreciable loss of plasma protein, the restored part thereof already on the 1st day of the postexperimental period exceeded the possible amount of de novo synthesis. This shows that plasma proteins have the capacity to be deposited in other fluid sectors of the body and, when necessary, they can rapidly restore the loss of plasma as it occurrred in the

recovery period following hypokinesia. Perhaps, in the presence of dehydration and decrease in liquid part of blood, as noted by K. I. Gogolev et al. [23], the migration of some proteins from plasma into the extravascular space prevents further decrease in volume of interstitial fluid, which limits the loss of body fluid and adequate redistribution thereof in the intravascular and extravascular spaces. If this is so, there is a logical explanation for the results of our first series of tests, where marked dehydration, mainly due to decrease in interstitial fluid volume, was not associated with a decrease in mass of plasma proteins (see Table).

At the present time, metabolism of albumin, which constitutes half the mass of plasma protein, has been well-studied by means of iodine-labeled albumin [24-26]. There are also works, in which an analogous method was used to examine metabolism of other plasma proteins--transferrin and γ-g-globulin [27]. Qualitatively, the results were the same for all proteins: a significant part (up to 70% in some studies, somewhat less than 50% in most cases) of the protein is outside the bloodstream and is exchanged relatively slowly with proteins located in blood plasma. In 1 day, up to 10-20 g of albumin alone is synthesized and broken down in a healthy male. One would expect that about the same amount is synthesized for other proteins. For this reason, disappearance of proteins from plasma during 48-h bed rest and restoration thereof within about the same time could be attributed to both breakdown to amino acids and synthesis de novo, as well as migration of some plasma proteins into intercellular fluid and subsequent return with the flow of lymph into the blood stream.

If the proteins of extracellular fluid were in complete equilibrium with plasma proteins, the extravascular pool of proteins would exceed the intravascular one by 10-12 times, whereas in actuality it is equal to the latter, at best. Hence, extracellular fluid is not something homogeneous, but apparently consists of different elements or compartments, the composition of which differs significantly and fluctuates in time. This idea is confirmed in direct studies of composition of lymph, which is also referable to extracellular fluid. It has been studied the best with regard to the lymph of the thoracic duct, catheterization of which is performed during treatment of inflammatory and necrotic processes in the abdominal cavity, primarily pancreatitis [22]. In the absence of acute inflammatory processes, this lymph contains about half as much protein as plasma; 24-h lymph content of the thoracic lymphatic duct also constitutes about half the plasma volume; for this reason, it can be considered that, under normal conditions, almost one-fourth of plasma proteins are deposited daily in lymphatic vessels of the abdominal and thoracic cavity.

Olszewski et al. [29] made studies in different physiological situations of composition of lymph circulating in the legs. It was found that it depends on the position of the limb and physical exercise. It was demonstrated that a change from orthostatic to erect position is associated with passage of plasma proteins from the blood stream into lymph. Analogous findings were made by Tarazi et al. [30] during short-term orthostatic tests, when it was found that there was a 4-6% decrease in plasma volume in 20 min of passive 50° orthostatic position, due to increased filtration of fluid into the interstitial space, but plasma protein concentration did not change appreciably. Senay and Kristensen [31] reported quite irregular increase in protein concentration in plasma in tests with thermal dehydration, when plasma volume decreased by 300-350 mℓ,

which, in our opinion, is also indicative of partial and uneven discharge of plasma proteins from the vascular system into the interstitial space. K. I. Gogolev et al. [23] observed a decrease in blood protein concentration in studies involving 7-day antiorthostatic hypokinesia and immersion, which was associated with a decrease in blood plasma volume. Finally, in our tests with 7-day water immersion (fifth series), we succeeded in demonstrating a decrease in total circulating protein mass, along with decrease in volume of intravascular fluid.

Thus, analysis of the literature and our material warrants the conclusion that plasma protein behaves differently under different conditions where there is a decrease in blood plasma volume: a) in some cases (this applies specially to rapid factors, in particular orthostasis) the decrease in blood plasma volume occurs exclusively due to filtration of fluid and electrolytes into the interstitial space; b) in other cases, it is also associated with exit of protein which, perhaps, is deposited in some compartments of extracellular space and can subsequently return into the vascular system together with lymph; c) in some cases, this protein can break down.

Analysis of the fate of plasma proteins when the intravascular volume is reduced, as well as the fate of extracellular fluid when there is redistribution of blood, indicates that the original conception of Henry and Gauer can be viewed only as an approximation to the complicated regulator mechanisms of fluid-electrolyte metabolism, since regulation of intravascular volume apparently depends much more on the fate of proteins than on the fate of fluid and electrolytes in the body.

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EFFECT OF SYDNOCARB ON CARDIORESPIRATORY SYSTEM DURING SEVEN-DAY WATER IMMERSION AND EXERCISE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 6, Nov-Dec 82 (manuscript received 4 Feb 82) pp 28-31

[Article by O. D. Anashkin and S. M. Belyayev]

[English abstract from source] To study physiological effects of weightlessness, 12 male volunteers, aged 25-33, were exposed to 7-day water immersion. The test subjects were divided into two groups of 6 in each: the first group subjects were given a new Soviet stimulant sydnocarb (3-(β-phenylisopropyl)-N-phenyl carbamoyl sydnonimine) and the second group subjects were given a placebo, using the double-blind method. To evaluate the cardiorespiratory function, the test subjects exercised on a bicycle ergometer before and after water immersion. During exercises ECG, heart rate, minute respiration volume, oxygen consumption, carbon dioxide production, cardiac output, oxygen pulse were recorded. The test subjects on the placebo showed a significant decrease of oxygen consumption at maximum workload. Those who were given sydnocarb maintained normal oxygen consumption during bicycle ergometry. The drug increased the workload per kg body weight, maintained physical work capacity, and improved the cardiovascular function after immersion.

[Text] Diverse physical factors (occlusive cuffs, LBNP [lower body negative pressure], local negative pressure and exercise) are used to prevent the adverse effects at the early stage of adaptation to weightlessness, during which one observes temporary decline of man's work capacity [1-4].

We did not encounter any information about using pharmacological agents to prevent the effects of the early period of adaptation in the literature available to us, although use of drugs could improve cosmonauts' well-being significantly, prevent motion sickness and increase overall work capacity in this period.

Our objective here was to assess the efficacy of a new Soviet work capacity stimulator, sydnocarb [5-7], on the functional state of the human cardiorespiratory system during 7-day immersion.

Methods

We conducted these studies with the participation of 12 healthy male volunteers 25-33 years of age. The physiological effects of weightlessness were simulated with 7-day water immersion by the method of "dry" submersion [8]. The first group consisted of 6 men who were given sydnocarb starting on the 1st day of immersion on the following program: 5 mg at lunch on the 1st day, 5 mg at breakfast and lunch on the 2d-4th day and 10 mg at breakfast, 5 mg at lunch on the 5th-7th days.

The second group of subjects (6 men) received placebo on the same program, and the principle of double "blind" control was used.

Arterial pressure (AP), heart rate (HR) and body temperature (TB) were recorded for the subjects 2 and 4 h after intake of the products.

In order to assess the functional state of the cardiorespiratory system before and after immersion, the subjects exercised on an isokinetic bicycle ergometer, on which the subjects pedaled in supine position. The work load constituted 600 kg-m/min for 9 min, after which it increased by 100 kg-m per min until the subjects refused to continue with the test. Various clinical criteria, which have been established to assess man's physical work capacity [9], could also serve as grounds to stop the test.

During exercise, we recorded the EKG in the V_1, V_s and aVF leads on a computer system which effected continuous monitoring of HR and analysis of EKG changes.

Before the exercise test, in the 8th min and last min of exercise, as well as in the 5th and 10th min of the recovery period (RP), we collected exhaled air in Douglas bags to determine minute volume (MV) (using a GSB-400 gas counter), oxygen uptake (OU) and carbon dioxide output on gas analyzers.

The method of CO_2 rebreathing [10] was used to determine minute circulation volume (MCV) at rest, in the 8th min of the test and 5th min of the RP.

Systolic and diastolic AP (AP_s and AP_d, respectively) were recorded by the tachooscillographic method using an AD-KTs instrument, at rest, in the 4th and 8th min of the test, as well as 1st, 5th, 10th and 15th min of the recovery period. We estimated stroke volume (SV), oxygen pulse and dual derivative ($HR \times AP_s$).

The studies were conducted in the mornings, at the same time of day, under conditions close to those used to determine basal metabolism. Background records were made after the subjects spent 1 h in horizontal position, 24 h before immersion. Postimmersion studies began 10-15 min after immersion, and the subjects continued to stay in horizontal position.

The results of theses studies were processed by the method of variants related in pairs, using Student's *t* criterion to assess mean differences.

Results and Discussion

We demonstrated normal parameters of the cardiorespiratory system in response to maximum physical load in all 12 subjects tested on the bicycle ergometer

before immersion (Tables 1 and 2). In both groups of subjects, average maximum load and volume of work performed were about the same.

Table 1. Dynamics of minute volume of respiration and oxygen uptake

TIME OF EXAMIN.	MV, L/MIN				OXYGEN UPTAKE							
					ML/MIN				ML/MIN/KG WEIGHT			
	PLACEBO		SYDNOCARB		PLACEBO		SYDNOCARB		PLACEBO		SYDNOCARB	
	I	II	I	II	I	II	I	II	I	II	I	II
AT REST	6,39 0,41	6,61 0,43	9,43 0,90	8,47 1,39	194 26,7	200 21,7	268 35,0	206 40,6	2,4 0.2	2,6 0,4	3,5 0,5	2,7 0,5
8TH MIN OF TEST	25,14 2,47	24,90 2,20	28,44 1,74	28,10 2,23	1325 139,4	1241 131,4	1480 132,9	1430 148,9	16,2 1,4	16,1 2,2	19,3 1,6	19,0 1,8
END OF TEST	67,99 7,97	69,86 5,98	68,84 6,77	72,88 9,40	3076 285,9	2726* 301,2	3084 310,3	2919 408,7	38,5 3,7	34,7* 3,9	40,0 3,5	38,3 4,7
5TH MIN OF RP	19,26 2,53	20,33 1,56	20,91 1,78	20,58 1,70	620 94,9	591 57,2	645 65,5	604 66,4	7,6 1,2	7,7 0,8	8,5 1,0	8,0 0,6
10TH MIN OF RP	12,84 1,68	13,22 0,81	14,98 1,75	15,62 2,02	393 55,4	377 44,4	460 47,6	455 55,0	4,7 0,4	4,7 0,4	6,1 0,7	6,0 0,6

Note: Here and in Tables 2 and 3: I--before immersion, II--after immersion.

*$P<0.05$, as compared to pre-immersion results.

**$P<0.1$, as compared to pre-immersion results.

During the 7 days of immersion, we failed to demonstrate changes in heart rate, arterial pressure or body temperature 2 or more h after intake of sydnocarb or placebo in any of the subjects at rest.

During exercise after immersion, there were minimal MV changes in both groups, whereas oxygen uptake showed virtually no change in the 8th min of exercise (see Table 1).

There was a reliable 11.4% decrease in oxygen uptake in subjects given placebo submitted to maximum work load, whereas in those given sydnocarb this parameter did not change, as compared to the pre-immersion level (see Table 1). The change in maximum oxygen uptake is indicative of the fact that there was reliable worsening of physical work capacity under the influence of immersion in subjects of the second group.

After the exercise test, oxygen uptake was restored at the same rate, as compared to base levels at rest, in both groups of subjects before and after immersion.

In the second group of subjects, there was a tendency toward decline (by 6.1%; $P<0.1$) in maximum work load from 1367 to 1283 kg-m/min, as well as in total volume of exercise performed (by 8.7%; $P<0.1$) from 13,450 to 12,283 kg-m. These parameters did not change in subjects given sydnocarb, constituting 1317 kg-m/min and 12,7'7 kg-m, respectively. Moreover, we observed a reliable increase

(by 2.4%; P<0.05) in amount of exercise performed per kg body weight, from 168 to 172 kg-m.

Table 2. Dynamics of some parameters of the cardiorespiratory system (M±m)

TIME OF EXAMIN.	MV, L/MIN				SV, ML/MIN				OXYGEN PULSE, ML/BEAT			
	PLACEBO		SYDNOCARB		PLACEBO		SYDNOCARB		PLACEBO		SYDNOCARB	
	I	II	I	II	I	II	I	II	I	II	I	II
AT REST	5,42 0,32	5,09 0,22	4,85 0,31	4,77 0,25	76,7 7,9	80,2 4,9	86,9 5,7	77,8** 3,4	2,8 0,4	3,2 0,4	4,7 0,5	3,4 0,7
8TH MIN OF TEST	12,69 1,47	13,58 0,95	14,20 1,11	14,36 1,29	118,3 16,5	116,3 16,2	139,8 11,8	125,8** 11,6	12,5 1,6	10,4 2,0	14,6 1,4	12,7* 1,7
END OF TEST	—	—	—	—	—	—	—	—	17,8 2,0	15,0* 1,8	18,3 1,8	16,3 2,3
5TH MIN OF RP	7,72 0,78	8,35 0,74	8,46 0,99	8,69 0,59	74,2 8,2	77,6 8,1	88,1 10,8	81,6 7,1	6,1 1,0	5,6 0,7	6,7 2,9	5,8 0,9
10TH MIN OF RP	—	—	—	—	—	—	—	—	4,0 0,6	3,7 0,5	5,0 0,6	4,6 0,7

Table 3. Dynamics of some parameters of the cardiovascular system (M±m)

TIME OF EXAMINATION	HR/MIN				AP_s, MM HG				DOUBLE DERIVATIVE $\times 10^2$, ARBITRARY UNITS			
	PLACEBO		SYDNOC.		PLACEBO		SYDNOC.		PLACEBO		SYDNOCARB	
	I	II	I	II	I	II	I	II	I	II	I	II
AT REST	72.8 5.3	63.8** 2.0	56.3 4.0	61.8 4.1	119.7 7.6	116.2 4.9	113.2 2.7	116.0** 4.7	88.1 11	74.1 3.9	63.8 3.6	72.0 5.8
4TH MIN OF TEST	103.2 5.6	111.8* 7.0	97.3 1.6	107.0* 6.9	162.2 7.2	158.7 7.4	142.5 7.8	111.2 5.5	108.7 11.9	182.4 17.0	139.1 11.1	117.2 12.1
8TH MIN OF TEST	109.8 6.7	122.3* 8.97	102.5 5.6	115.5* 7.8	166.2 8.0	166.5 6.1	150.5 6.6	144.0 7.1	183.2 11.6	205.2* 19.4	155.1 11.2	108.8 13.0
END OF TEST	177.3 5.2	183.0 3.4	168.7 5.2	178.8 2.6	—	—	—	—	—	—	—	—
1ST MIN OF RP	110.8 5.6	142.0 7.7	126.8 7.7	110.5 8.5	168.2 9.0	115.2* 8.6	151.7 9.1	150.0 5.2	235.7 12.1	206.7** 17.2	192.3 15.9	211.1 16.0
5TH MIN OF RP	101.8 3.9	100.2 4.0	96.8 3.9	108.2 6.1	138.8 5.2	135.5 7.0	128.8 4.3	133.0 5.2	145.4 7.4	119.2 13.2	125.1 7.9	143.2 7.6
10TH MIN OF RP	99.7 3.3	104.2 4.5	93.8 3.7	102.5** 4.1	126.7 3.4	118.5 6.8	121.2 5.1	118.3 3.6	126.5 6.2	123.9 19.2	111.2 8.5	121.6 6.9
15TH MIN OF RP	92.3 3.1	96.5** 3.0	87.2 4.0	96.5** 3.2	127.0 4.1	115.8** 5.3	116.2 4.5	116.2 3.1	117.5 6.7	121.1 7.5	101.6 7.4	112.5** 3.9

After immersion, the subjects failed to demonstrate appreciable changes in cardiac output [minute volume] during exercise (see Table 2). In the 4th and 8th min of exercise after immersion, the heart rate was reliably higher in both groups than the base values, whereas at the level of maximum work load the changes in this parameter were insignificant.

Restoration of heart rate to base values was delayed in subjects given placebo, whereas in those given sydnocarb it did not change.

During postimmersion exercise, stroke volume did not differ reliably from background values in both groups of subjects; however, in the 1st group, there was some tendency toward decline of this parameter in the 8th min of exercise (by 10%; P<0.1). By the 5th min of the recovery period, stroke volume returned to base levels at rest (see Table 2).

Oxygen pulse, the rate of which determines tissular capacity to utilize oxygen, diminished by 15.7% after immersion in the second group of subjects, whereas it did not undergo appreciable changes in the first group. A decline was noted in the first group in the 8th min of immersion (see Table 2).

In both groups, AP_s did not change appreciably during exercise under the influence of immersion; however, we were impressed by a reliable drop of AP_s in the second group of subjects, in the 1st min of the recovery period after immersion, as compared to background findings (Table 3).

The increase in the dual derivative, which is an indirect indicator of myocardial oxygen requirement, in the second group of subjects in the 8th min of exercise is indicative of less economical cardiac function during this postimmersion period. There were no changes in this parameter in the first group of subjects (see Table 3).

Thus, intake of sydnocarb during water immersion by healthy people is associated with retention of parameters of maximum oxygen uptake during exercise, total volume of work performed on the bicycle ergometer, increased amount of exercise per kg body weight, faster recovery of heart rate and adequate AP reaction to the physical load.

It was demonstrated that there is a decrease in activity of the mediator link of the adrenosympathetic system during water immersion, which occurs on the level of dopamine, the precursor of norepinephrine, which leads to absolute decrease in norepinephrine content of blood [11]. In the opinion of some authors, this decrease is attributable to diminished sympathetic vasomotor activity as a result of decrease during immersion in quantity of stimuli that elicit release of norepinephrine from nerve endings [11].

Our findings indicate that intake of sydnocarb, the new Soviet stimulator, by man during 7-day immersion causes him to retain physical work capacity and improves the state of the cardiovascular system during performance of maximum physical work after immersion.

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HUMAN EQUILIBRIUM DURING ROTATION AT DIFFERENT LEVELS OF HYPERGRAVITY

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 6, Nov-Dec 82 (manuscript received 4 Aug 81) pp 32-34

[Article by A. R. Kotovskaya, L. N. Gavrilova, R. R. Galle, F. Glavacka, M. Schalling and P. Duda (USSR and CSSR)]

[English abstract from source] This paper discusses the gravity (of up to 2 g) effect on the upright stability of 16 test subjects exposed either to centrifugation or to artificially increased body weight (with uniformly distributed loading). During centrifugation the stabilographic parameters increased significantly at every gravity level. In the experiments with artificially increased body weight the area of the vector stabilograms also increased significantly. The comparison of the two experimental runs suggests that disorders in the upright stability are caused by the rotation factor rather than by the artificially increased body weight.

[Text] Disturbances referable to postural equilibrium, which are due to man's vital functions in rotating systems, have been studied rather comprehensively [1-3]. However, in these works, questions dealing with the effect on equilibrium function of long-term presence in a revolving habitat when gravity changes were not dealt with. At the same time, a change in gravity could affect performance of work operations in a spacecraft with artificial gravity on board, which is created by means of rotation [4, 5].

Our objective here was to study the effect of artificial gravity of up to 2.0 G on man's stability in erect position during rotation and with simulation of hypergravity by using weights to artificially increase his weight.

Methods

Two series of studies were conducted. The first was performed on a centrifuge in the presence of hypergravity. There was a cabin on the centrifuge that was intended to accommodate a subject for several hours. The cabin was secured at different distances from the axis of rotation, which enabled us to conduct tests with artificial gravity of 1.09, 1.53 and 2.0 G retaining a constant angular velocity of 15.3 r/min. The artificial gravity vector was always perpendicular to the floor of the cabin and parallel to man's longitudinal body axis when standing on the stabilographic platform (Figure 1a).

The second series of studies with artificial addition of weight was conducted in the laboratory, without rotation. A 1.09-, 1.37- and 1.53-fold increase in weight, as compared to the base weight, was produced by distributing weights uniformly on the head, chest, back, arms and legs of the subjects (see Figure 1b) with retention of the initial position of the body's center of gravity.

We examined human equilibrium function by the stabilographic method [6]. In the first series of studies, we analyzed the number and amplitude of oscillations of a subject standing on the stabilographic platform, in the frontal and sagittal planes; in the second series, we studied the area of the vectorstabilogram.

Stabilographic was performed with the subjects standing "at attention" in erect position with the eyes open and closed, 60 s in each case.

There were 5 men who participated in the first series of studies and who had high vestibular stability; 11 participated in the second series. All of the subjects were men 22-35 years of age. In all, we conducted 96 stabilographic tests. The results were submitted to statistical processing.

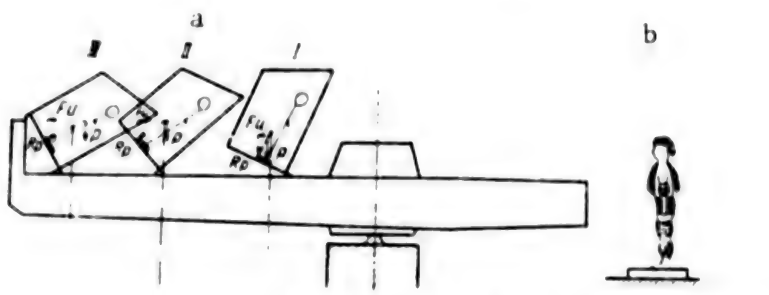

Figure 1. Diagram of arrangement of cabin on centrifuge console and forces to which man was exposed when standing on stabilographic platform (a), and diagram of distribution of weights on human body (b)

F_c) centrifugal force
P) gravity
R) equivalent centrifugal force and gravity (AG [artificial gravity])
I) R_p = 1.09 G
II) R_p = 1.53 G
III) R_p = 2.0 G

The dot shows the radius of cabin center of masses and rectangle--stabilograph.

Results and Discussion

During rotation in the centrifuge cabin with AG [artificial gravity] of up to 2.0 G, the subjects present distinct worsening of equilibrium against a background of relatively good clinical endurance of rotation.

As can be seen in Figure 2a, the amplitude of body oscillations when standing with the eyes open increased with statistical reliability at all levels of AG, as compared to background data. There was an increase in stabilogram amplitude in the frontal plane of 117% with AG of 1.09 G, 190% with AG of 1.53 G and 220%

with AG of 2.0 G. Comparable findings were made with regard to parameters in the sagittal plane.

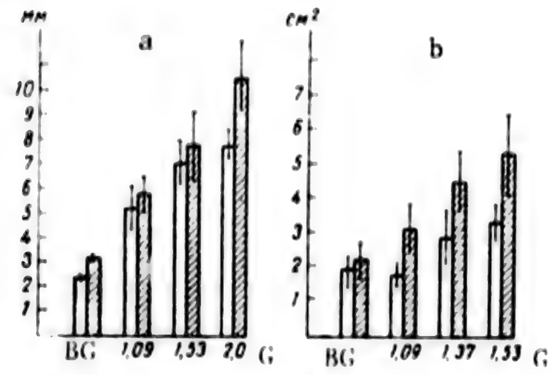

Figure 2.
Stabilographic parameters at different levels of gravity during rotation (a) and with use of weights (b)

X-axis, level of gravity; y-axis, amplitude of oscillations of human body (left) and area of vector-stabilogram (right).

White columns--eyes open, cross-hatched--eyes closed.

BG) background

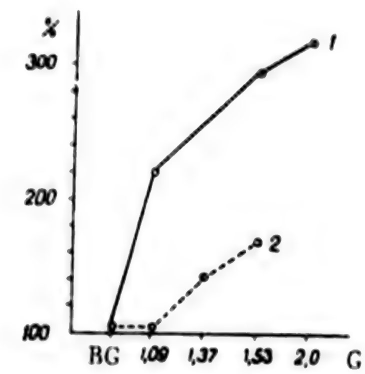

Figure 3.
Man's stability in erect position as a function of gravity level
1) change in amplitude of body oscillations in frontal plane (% of background) when rotating with accelerations
2) change in vectorstabilogram area (% of background) with use of weights on body.

BG) background
X-axis, gravity (artificial increase in weight); y-axis, percentile change in parameters, in relation to background.

When the eyes were closed, there was also statistically reliable increase in amplitude of body oscillations, but to a somewhat lesser degree than when standing with the eyes open. Thus, there was a 75% increase with AG of 1.09 G, 140% with AG of 1.53 G and 220% with 2.0 G.

There was an increase in number of oscillations when standing with the eyes open at all levels of AG. Statistically reliable differences in number of oscillations were demonstrable in the frontal plane at all levels of AG. In the sagittal plane, the change in number of oscillations when standing with the eyes closed was in the nature of a marked tendency in the direction of increase; however, in view of the wide scatter of individual parameters, no statistical differences were demonstrated.

Consequently, when rotating with AG of up to 2.0 G, the subjects presented an increase of stabilographic parameters, the changes in number and amplitude of body oscillations being related to level of accelerations.

In the series with use of weights, we observed an improved capacity to maintain an erect position (see Figure 2b). With increase in weight coefficient from 1.09 to 1.53 units, the area of the vectorstabilogram increased reliably. When subjects were tested with the eyes closed, there was more appreciable change in

area of the vectorstabilogram. In addition, in this series, with increase in weight there was a gradual tendency toward decrease in frequency parameter of the stabilogram, particularly in the sagittal plane.

Consequently, our findings are indicative of an increase in stabilographic parameters in the presence of both increased gravity and artificially increased weight. However, as can be seen in Figure 3, a greater increase in stabilographic parameters corresponded to the values obtained during rotation with AG of up to 2.0 G when standing with the eyes open, than with the use of weights. Thus, a comparison of the results of these series of studies indicates that the rotation factor plays a larger part than gravity in onset of disturbances referable to stability in erect position during rotation with high levels of AG.

According to the hypothesis of Smitt [7], the reactions of the human body to a change in gravity, both in the direction of increase and decrease, as compared to earth's gravity, are effected by the same mechanisms and are qualitatively similar. If we were to extrapolate the results of these studies to a spaceflight with AG not exceeding 1.0 G, it can be assumed that there will be a wider amplitude of oscillations of the body in erect position than on the ground. The number of oscillations will increase less than when rotation is effected at earth's gravity.

These findings warrant the assumption that a change in AG aboard spacecraft in the range of up to 1.0 G could lead to disturbances referable to equilibrium, which increase with increase in AG.

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ENERGETIC REACTIONS IN RAT SKELETAL MUSCLES AFTER SPACEFLIGHT ABOARD COSMOS-936 BIOSATELLITE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 6, Nov-Dec 82 (manuscript received 19 Mar 82) pp 34-37

[Article by E. S. Mailyan, L. B. Buravkova and L. V. Kokoreva]

[English abstract from source] The respiration of mitochondria isolated from mixed skeletal muscles of hindlimbs of rats flown for 18.5 days on Cosmos-936 was investigated polarographically. At R + 10 hours the rate of mitochondrial respiration in different metabolic states during the oxidation of succinic acid and NAD-dependent substrates declined. The enzyme activity of mitochondrial cytochrome oxidase and cytosol lactate dehydrogenase diminished. At R + 25 days both aerobic and anaerobic oxidative processes increased, thus leading to the recovery of the parameters (sometimes they not only returned to the norm but exceeded it).

[Text] The processes of tissular respiration and bioenergetics responsible for supplying energy for contractile function of muscles, which largely determine the level of energy expended by the body, are among the criteria for evaluation of the state of the muscular system in weightlessness. However, some difficulties are involved in studying energy expenditure in cosmonauts and astronauts to determine the true effects of weightlessness, since the body's reactions to being outside the gravity field are modified under the influence of a powerful system of preventive measures and emotional stress. This is why animal studies during long-term spaceflights are the only experimental model that permits evaluation of the significance of the gravity field in formation of energetic homeostasis of the body and degree of deleterious effect of weightlessness.

Metabolic disturbances were demonstrated in skeletal muscles of animals flown aboard biosatellites of the Cosmos series for 18.5-22 days, and the severity of these disturbances depends largely on the proportion of fast and slow fibers. In mixed muscles, changes are observed on the 1st postflight day in activity of enzymes of glycolysis, of the pentose-phosphate pathway of glucose oxidation, ATPase of myosin, as well as decrease in phospholipid content of mitochondrial and sarcoplasmic fractions and reduction in volume of the sarcoplasmic network [1-4]. In addition, depressed metabolism was demonstrated in the parts of the brain whose function is related to motor activity [5]. All this could lead to

change in intensity and efficiency of respiration in muscle cells, impaired accumulation of energy and attenuated synthesis of macroergic compounds.

Our objective here was to investigate the different stages of biological oxidation in rat muscle tissue after an 18.5-day spaceflight.

Methods

We examined the group of posterior thigh muscles of rats 10 h (FW_2) and 25 days (FW_3) after the spaceflight, at the same times after termination of a ground-based synchronous experiment (SW_2 and SW_3) and vivarium control experiment (VC_2 and VC_3).* The characteristics of animal groups aboard the biosatellite were described previously [6]. In each group, we examined material from five animals. The muscles were excised 15-20 min after decapitation, then frozen in liquid nitrogen and stored at a temperature of -70°C for 3 days. After thawing, we extracted mitochondria from muscles by the method of differential centrifugation [7], and in them we made a polarographic analysis of oxidative phosphorylation [8].

Cytochrome oxidase (CCO) activity was evaluated on the basis of dynamics of mitochondrial respiratory rate with addition of increasing concentrations of cytochrome c. Enzymatic activity was characterized by a curve derived in a system of coordinates referring the rate of O_2 uptake (y-axis) to cytochrome c concentration (x-axis), taken in the form of reciprocals (Figure 1). We considered the reciprocal of the length of the intersected segment on the y-axis as CCO activity.

Overall activity of lactate dehydrogenase (LDH) was determined in supernatant recovered in the course of isolating mitochondria after the last centrifugation, using an SF-16 spectrophotometer at wavelength of 600 nm.

Results and Discussion

Figure 2 illustrates the rate of respiration of mitochondria in different metabolic states. This figure shows that, when mitochondria are incubated in the presence of different oxidative substrates, the respiratory rate is considerably lower in the flight group than in the synchronous one (top row of columns). There was even more drastic depression of respiration in the flight group after adding ADP (44, 46 and 34% decline, respectively, with no change in respiratory control). Phosphorylative respiration which then occurred was related to accumulation of energy in macroergic compounds. Considering that ADP-dependent respiration is a biochemical model of a functioning muscle [8], it can be believed that there is particularly marked manifestation of the inhibitory effect of weightlessness on respiration and bioenergetics of muscles during muscular function.

The results of evaluating CCO, the enzyme of terminal oxidation (see Figure 1) revealed that its activity was also reliably diminished on the first postflight day. CCO activity was 56% lower in the flight group of animals (14.37±1.6 nmole O_2/mg protein/min) than in the synchronous group (32.63±5.73) and 50% lower than in the control group (28.67±3.75).

*F--flight, W--weightlessness, S--synchronous, V--vivarium, C--control.

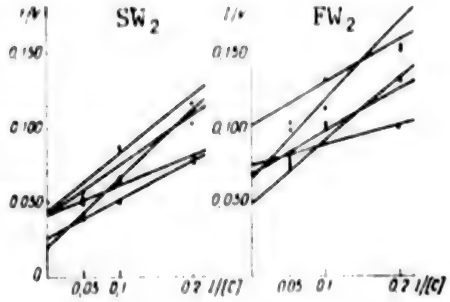


Figure 1.
CCO activity in suspension of skeletal muscle mitochondria on 1st postflight day in synchronous (SW_2) and flight (FW_2) series
V) respiratory rate (in nanomole O_2/mg protein/min)
[C]) cytochrome c concentration (μmole)

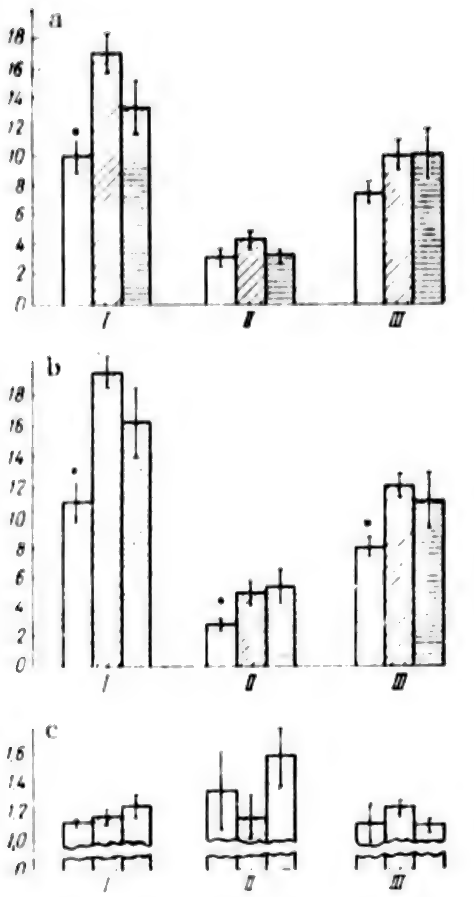
At the early readaptation stage, along with decline of parameters of aerobic respiration, there was attenuation of anaerobic glycolytic processes. This is indicated by the dynamics of change in total LDH activity (Figure 3), which decreased by 47% in the flight group, as compared to the synchronous group, and by 52%, as compared to the control group. In all likelihood, attenuation of glycolytic processes in the early postflight period is the most typical reaction of mixed type muscles. This is also indicated by the decrease in total LDH activity in the quadriceps [1] and increase in glycogen content of the gastrocnemius [9]. Intensification of glycolytic processes, with a shift of the isozyme spectrum in the direction of M fractions [10] was noted in the soleus, which consists primarily of red fibers. The latter circumstance is apparently related more to transformation of part of the slow oxidative fibers into rapid glycolytic ones [12] than to hypoxia [11].

Characteristics of mitochondrial respiration on 25th day of recovery period (respiratory rate in nanomoles O_2/mg protein/min)

ANIMAL GROUP	SUBSTRATE RESPIRATION			ADP DEPENDENT RESPIRATION		
	SUCCINATE	GLUTAMATE	α-KETO-GLUTARATE	SUCCINATE	GLUTAM.	α-KETO-GLUTARATE
FW_3	26,6±3,49	9,54±1,87	21,44±4,05	29,85±4,26	12,14±1,29	22,46±4,28
SW_3	21,18±1,31	5,96±1,06	16,96±1,69	24,14±1,46	9,04±0,74	19,71±2,87
VC_3	25,0±1,14	7,64±0,62	20,41±1,04	30,44±1,66	11,49±1,22	24,15±1,02

The results of tests conducted on the 25th day of the readaptation period revealed that the above-described changes in aerobic and anaerobic oxidation were followed by complete restoration of all parameters, and moreover there were signs of some supercompensation (see Table and Figure 3). The described changes coincided with the patterns previously established aboard Cosmos-605 biosatellite [13, 14].

A comparison of parameters reflecting the direction and rate of reactions at different stages of biological oxidation leads to the conclusion that there were severely inhibited oxidative processes (both aerobic and anaerobic) in mixed muscles of rats after termination of the 18.5-day flight. Attenuation of the flow of accumulated energy under such conditions could lower the energy potential of the cell and have an adverse effect on biosynthetic processes, metabolic reactions and muscular functions related to expenditure of energy. This signal apparently becomes the cause of subsequent increase in



← Figure 2.
Characteristics of mitochondrial respiration in muscles with oxidation of 20 mmole succinate (I), 4 mmole glutamate (II) and 15 mmole α-ketoglutarate (III) in flight (white columns), synchronous (slanted lines) and control (horizontal lines) groups of rats on 1st day of readaptation period.

a, b) substrate and ADP-dependent respiration, respectively (in nmole O_2/mg protein/min)

c) respiratory control

Asterisk shows reliable differences between flight and synchronous groups.

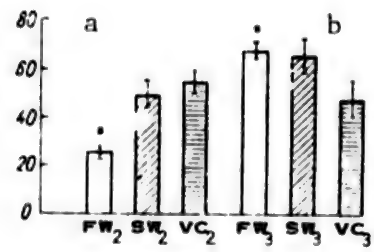


Figure 3.
Total LDH activity (in IU/mg protein) in muscles on 1st (a) and 25th (b) days of readaptation period. Asterisk shows reliable differences between flight and control groups.

biogenesis and functional activity of mitochondria. With increase in capability of the mitochondrial system there is increase in ATP production per unit tissue mass and the ATP deficiency is eliminated. In our studies, this assumption was confirmed by the increase in functional activity of mitochondria and in mitochondrial protein content by the 25th day. One should take the impairment in processes of energy supply to muscles when examining the causes of change in state of the motor system of man on the first few days after spaceflights.

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ACTIVITY OF TRICARBOXYLIC ACID CYCLE OXIDATIVE ENZYMES IN SKELETAL MUSCLES OF HYPOKINETIC RATS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 6, Nov-Dec 82 (manuscript received 16 Nov 81) pp 37-41

[Article by Yu. A. Ganin]

[English abstract from source] The study of 165 rats exposed to 60-day hypokinesia demonstrated a decrease in the quantity of mitochondrial protein and a decline in the activity of mitochondrial forms of NADP-isocitrate dehydrogenase (NADP-ICDH) and NAD-malate dehydrogenase (NAD-MDH), as well as NAD-ICDH, succinate dehydrogenase (SDH) and α-ketoglutarate dehydrogenase (α-KGDH). The maximum decline in the protein content was seen on day 60, and in the enzyme activity on day 7. As the hypokinetic exposure continued, the activity of mitochondrial NAD-MDH and NADP-ICDH slightly increased. The NADP-MDH activity decreased only at later stages of hypokinesia. The changes in cytoplasmic NAD-MDH, NADP-ICDH and NADP-MDH were less expressed. On day 25 of the recovery period the activity of NAD-ICDH and NADP-ICDH was significantly higher than in the controls, that of mitochondrial NAD-MDH returned to the normal, and the activity of SDH and α-KGDH remained noticeably lower.

[Text] Under hypokinetic conditions, the greatest changes occur in skeletal muscles [1], and impairment of energy metabolism is one of the pathogenetic factors [2]. Efforts have been made to study the activity of enzymes of the tricarboxylic acid cycle (TAC) by means of histochemical methods, which demonstrated some decline of dehydrogenase activity on the tissular level [3-6]. However, in order to gain a complete idea about the course of oxidative processes in the TAC it is necessary to conduct a combined study of enzymes in subcellular structures (primarily in mitochondria) and differentiate between changes in analogous enzymes of cytoplasm.

For this purpose, a study was made of cytoplasmic and mitochondrial forms of NAD-NADP-dependent isocitrate dehydrogenases and malate dehydrogenases, as well as α-ketoglutarate and succinate dehydrogenases in the mitochondrial fraction of rats at different stages of hypokinesia and in the recovery period.

TAC oxidative enzyme activity in rat skeletal muscles, hypokinesia and recovery period (nM NADP·H₂/min)

Enzyme	Activity	Animal group	Day of hypokinesia: 7	[illegible]	[illegible]	[illegible]	Recovery period (25th day)
NAD-ICDH	Specific	Control	55±2 (7)	50±3 (7)	43±1 (7)	39±2 (7)	35±3 (7)
		Experim.	47±3 (7)*	35±3 (7)*	38±3 (7)	29±3 (7)*	66±5 (7)*
	General	Control	170±7 (7)	185±8 (7)	140±5 (7)	181±5 (7)	114±9 (7)
		Experim.	130±7 (7)*	116±7 (7)*	89±6 (7)*	83±9 (7)*	208±17 (7)*
Mitochondrial NADP-ICDH	Specific	Control	214±10 (7)	227±5 (8)	215±6 (7)	172±15 (10)	152±12 (7)
		Experim.	120±13 (7)*	203±17 (7)	159±8 (7)*	188±17 (7)	252±24 (7)*
	General	Control	693±22 (7)	721±23 (8)	699±27 (7)	723±60 (10)	487±38 (7)
		Experim.	291±15 (7)*	515±60 (7)*	368±22 (7)*	547±52 (7)*	789±80 (7)*
Cytoplasmic NADP-ICDH	General	Control	1223±54 (7)	1205±62 (8)	1102±54 (7)	1452±84 (8)	1320±97 (7)
		Experim.	953±58 (7)*	1029±63 (7)	1133±52 (7)	1583±133 (7)	1349±132 (6)
Mitochondrial NAD-MDH	Specific	Control	1211±49 (7)	1145±57 (8)	1244±80 (7)	726±81 (8)	989±84 (7)
		Experim.	544±42 (7)*	704±59 (7)*	1016±92 (7)	646±60 (7)	1051±75 (7)
	General	Control	3505±122 (7)	3624±129 (8)	4000±194 (7)	2664±248 (8)	2988±249 (7)
		Experim.	1321±70 (7)*	1761±151 (7)*	2340±240 (7)*	1872±251 (7)*	3274±241 (7)
Cytoplasmic NAD-MDH, μM NAD·HM$_2$/min	General	Control	219,5±6,0 (7)	230,9±8,2 (8)	250,5±12,3 (7)	150,5±12,4 (8)	350,7±20,3 (7)
		Experim.	216,7±4,8 (7)	190,5±8,3 (7)*	225,2±10,6 (7)	125,7±11,6 (7)	226,7±14,1 (7)*
Mitochondrial NADP-MDH	Specific	Control	10,2±0,6 (7)	8,9±0,3 (8)	8,4±0,4 (7)	18,7±1,0 (10)	8,1±0,6 (7)
		Experim.	10,1±0,8 (7)	8,6±1,0 (7)	8,6±0,6 (7)	11,8±1,4 (7)*	7,7±0,7 (6)
	General	Control	34±2,6 (7)	29±1,4 (8)	27±1,0 (7)	84±8,2 (10)	26±1,1 (7)
		Experim.	28±2,7 (7)	27±2,6 (7)	19±1 (7)*	35±5 (7)*	24±1,7 (6)
Cytoplasmic NADP-MDH	General	Control	474±11 (7)	442±16 (8)	395±9 (7)	1018±87 (7)	346±16 (7)
		Experim.	437±16 (7)	394±28 (7)	307±12 (7)*	1092±121 (7)*	363±18 (6)
SDH, nM substrate/min	Specific	Control	142±6 (7)	129±10 (8)	143±12 (7)	81±7 (10)	241±17 (7)
		Experim.	101±7 (7)*	97±7 (7)*	127±7 (7)	66±6 (7)	106±16 (6)*
	General	Control	453±35 (7)	507±28 (8)	460±50 (7)	346±42 (10)	740±52 (7)
		Experim.	287±33 (7)*	248±21 (7)*	294±20 (7)	193±23 (7)	499±51 (6)*
α-KGDH, nM substrate/min	Specific	Control	105±7 (7)	91±6 (8)	99±8 (7)	59±4 (10)	172±17 (7)
		Experim.	80±6 (7)	77±7 (7)*	96±5 (7)	50±6 (7)	113±012 (6)*
	General	Control	338±20 (7)	290±15 (8)	321±23 (7)	250±18 (10)	529±51 (7)
		Experim.	227±23 (7)*	190±16 (7)*	222±16 (7)*	143±18 (7)*	324±36 (6)
Protein content of mitochondrial fraction, mg/g tissue		Control	3,201±0,074 (7)	3216±0,077 (8)	3,240±0,080 (7)	4,284±0,298 (10)	3,216±0,214 (7)
		Experim.	2,700±0,108* (7)	2,494±0,128* (7)	2,310±0,055* (7)	2,854±0,173* (7)	3,116±0,074 (7)

*P<0.05. Number of animals is given in parentheses.

Methods

The studies were conducted on 165 male albino rats with initial weight of 160-170 g, 78 of which served as a control. The animals were kept in small individual cages made of plexiglas to restrict their motor activity. They were submitted to hypokinesia for 60 days. The animals were decapitated on the 7th, 30th, 45th, 60th days of hypokinesia and on the 25th day of the recovery period. We took the posterior group of thigh muscles (about 2 g) for examination, after removing connective tissue elements. The mitochondrial fraction and fraction containing the soluble part of cytoplasm were recovered by the method of differential centrifugation of Holloszy [7] and Sottocasa [8] in a refrigerated room at 0-4°C. We used the medium proposed by Watanabe [9], which contains 0.2% Triton X-100, for solubilization and stabilization of mitochondrial enzymes. Isocitrate dehydrogenase and malate dehydrogenase activity was determined with a spectrophotometer, according to formation of reduced forms of pyridine nucleotides, using the incubation media described for NAD-isocitrate dehydrogenase (NAD-ICDH, EC 1.1.1.41) by Plaut [10], for NADP-isocitrate dehydrogenase (NADP-ICDH, EC 1.1.1.42) by Salganicoff and Koeppe [11], for NAD-dependent malate dehydrogenase (NAD-MDH, EC 1.1.1.37) by Ochoa [12], for NADP-malate dehydrogenase (NADP-MDH, EC 1.1.1.40) by Brdiczka and Pette [13]. We determined activity of succinate dehydrogenase (SDH, EC 1.3.9.91) [14] and α-ketoglutarate dehydrogenase (α-KGDH, EC 1.2.4.2) according to Gubler [15], using dichlorophenoline dophenol as electron acceptor. Protein was assayed by the method of Lowry [16]. We calculated specific (per mg protein) and overall (per g tissue) activity of the enzymes.

Results and Discussion

Our results revealed that prolonged restriction of movement elicits progressive decrease in protein of the mitochondrial fraction (see Table), apparently due to change in quantitative composition of mitochondria and qualitative disturbances of membrane structures [12]. A decrease in protein synthesis could also be a cause of this [17].

On the 7th, 30th, 45th and 60th days of hypokinesia, overall activity of enzymes that oxidize isocitrate was 34, 21, 20 and 6% lower, respectively, than in the control. The decline was attributable mainly to mitochondrial forms of enzymes, i.e., the enzymes of the TAC [19]. There was appreciable decrease in NADP-ICDH at the early stages of hypokinesia, while NAD-ICDH remained quite low up to the 60th day. Cytosol NADP-ICDH activity diminished moderately on the 7th day, but thereafter differed little from the control. The demonstrated differences are apparently attributable to the dissimilar functions of enzymes in the cell. NAD-ICDH, an allosteric enzyme, is activated by ADP, the oxidized form of NAD and, to a lesser extent, by cyclic AMP [10]. The rate of the reaction they catalyze is similar to that of the entire cycle. Hence it can be determined that the enzyme is capable of limiting the "carrying" capacity of the TAC. NADP-ICDH catalyzes a reversible reaction. According to the activity of this enzyme, it plays a large part in oxidation of isocitrate and regulation of the pool of reduced NADP in mitochondria, particularly with regard to synthetic processes in cytoplasm [19]. Mitochondrial NADP·H_2 can also be used for energy needs [20]. For this reason, the decline we demonstrated in this study in levels of enzymes that catalyze oxidation of isocitrate over

both the NAD- and NADP-dependent pathways could limit the flow of oxidized substrates in the TAC and restrict formation of reduced pyridine nucleotides that the cell uses to generate ATP and reducing synthesis, particularly in the mitochondrial compartment. On the 25th day, overall oxidation of isocitrate was 22% greater than in the control. There was particular increase in NAD-ICDH activity, which could be indicative of increased functional activity of mitochondria and change in regulatory parameters of ATP/ADP and NAD/NAD•H_2. The increase in activity of NADP-ICDH is apparently related to intensification of biosynthetic processes upon returning to a normal mode of physical activity.

Upon analyzing the changes in NAD-MDH, we were impressed by the sharp decline of activity of its mitochondrial form as early as the 7th day, which is consistent with data in [21]. With increase in duration of hypokinesia, there was gradual increase in activity of this enzyme, and this could be evaluated as a compensatory reaction. In the recovery period, this parameter dropped to control levels. The cytoplasmic form of NAD-MDH demonstrated a decrease in activity at the late stages of hypokinesia, and it increased in the recovery period. Considering the role of this enzyme in transport of reducing equivalents, one would think that such redistribution of activity of isoforms of NAD-MDH is indicative of impairment of this process. As compared to other TAC enzymes, NAD-MDH activity was rather high and did not limit the rate of the cycle [22], even with the demonstrated decline (by 63%), although we cannot rule out the influence of oxaloacetate, which is formed in this reaction, on activity of cyctrate synthetase, the "key" enzyme of the TAC.

There was no appreciable change in overall NADP-MDH activity during hypokinesia and the recovery period, but there was an increase in cytosol NADP-MDH activity and decrease of its activity in mitochondria on the 60th day. Since the role of NADP-MDH in different compartments of the cell (let alone skeletal muscles) is not sufficiently clear, it is difficult to assess the possible causes and consequences of these disturbances. NADP-MDH is not one of the TAC enzymes, and it catalyzes a reversible reaction conjugated with the cycle of reduction carboxylation of pyruvate, participating both in the early stages of neoglucogenesis and supplying the Krebs' cycle with oxidation substrate--malic acid [13]. We believe that its reaction to hypokinesia that is different from the one of the other enzymes, is indicative of weak link between this enzyme and energy metabolism, while the later change in activity suggest that NADP-MDH disturbances are secondary, and that there are other regulatory mechanisms for this enzyme.

Since SDH is a structural element of the internal mitochondrial membrane, a decline in activity of this enzyme is usually attributed to a decrease in quantity of mitochondria. In our experiments, the decrease in SDH activity was due expressly to a decrease in mitochondrial protein, but it was also associated with decrease in specific activity, perhaps as a result of certain disturbances in TAC regulation. The dynamics of decrease in α-KGDH activity did not differ appreciably from SDH. Interestingly, on the 25th day of the recovery period both enzymes showed a decrease in activity, which could be the result of structural changes in mitochondria or influence of factors that limit synthesis of SHD and α-KGDH. Apparently the recovery time was not sufficient for normalization of enzyme activity.

Analysis of TAC enzyme activity at different terms of hypokinesia revealed that, at the short term, depression of oxidative processes in the TAC is due mostly to decrease in specific enzyme activity, and with extension of the experiment this parameter gradually grew (to the most marked extent for NADP-ICDH and NAD-MDH). On the 45th and 60th days of immobilization, overall enzyme activity diminished chiefly due to decrease in amount of mitochondrial protein, the only exception being NAD-ICDH which has regulatory mechanisms that differ from those of the other enzymes. The activity of cytoplasmic isocitrate and malate dehydrogenases changed to a lesser extent, but these disturbances were associated with a change in proportion of mitochondrial and cytoplasmic forms of the enzymes, which could be related to diminished migration into mitochondria of reduced equivalents via "shuttle" mechanisms. According to the extent of diminished activity of enzymes localized in mitochondria, such alteration of activity of oxidative enzymes, combined with diminished production of reduced equivalents in mitochondria proper, is one of the principal causes of limited synthesis of macroergic compounds and disturbances in energy metabolism of skeletal muscles under hypokinetic conditions.

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INCREASED RAT SENSITIVITY TO SO_2 DURING LONG-TERM HYPOKINESIA

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[Article by A. I. Bokina, V. K. Fadeyeva and Ye. M. Vikhrova]

[English abstract from source] The effect of atmospheric contaminants on animals exposed to prolonged hypokinesia was investigated. A quantitative correlation between the resistance and the concentration of an atmospheric contaminant (sulfur oxide--SO_2) was established, using concentration-time and concentration-effect relations.

[Text] It was previously established [1-3] that long term exposure of animals to chemicals (phenol, sulfur dioxide, pesticides) accelerates development of pathological states (silicosis, hepatitis, nephrosis, hormone deficiency, cardiovascular pathology). All this is indicative of the greater sensitivity to toxic factors of organisms with altered resistance.

Our objective here was to investigate the distinctions of effects of atmospheric pollutants on animals submitted to prolonged hypokinesia and to determine the quantitative nature of changes in an organism with attenuated resistance to chemical pollutants of atmospheric air on the basis of "concentration-time" and "concentration-effect" functions.

Methods

The studies were conducted on 160 male rats weighing 190±10 g. We selected the most widespread atmospheric pollutant, sulfur dioxide (SO_2), in different concentrations as the model agent.

The animals were placed in 200-ℓ chambers for around the clock inhalation of the gas, and a vapor-air mixture of SO_2 was delivered into these chambers from tanks by means of a batching device under pressure, at the rate of 25-30 ℓ/min. The concentration of the tested gas mixture was checked daily. SO_2 content was assayed by the colorimetric method, which is based on absorption of SO_2 from air by sodium tetrachlormercurate solution.

The model of prolonged hypokinesia was used [5] to predict the degree of deviation in the course of pathological processes under the effect of chemicals.

Dynamic studies were made during the experiment of overall exchange of gases, pyruvic acid content in blood, activity of transketolases of erythrocytes, morphology of erythrocytes and leukocytes, phagocytic activity of leukocytes, blood sulfhydryl group activity, total protein and proportions of protein fractions in blood serum, parameters of calcium metabolism, weight gain, static work capacity and others.

In order to examine the "concentration-time" function (first series of experiments), we used 2 groups of animals for each of 4 tested SO_2 concentrations (20.0, 10.0, 2.0 and 0.2 mg/m^3). The animals of one group were kept in special cages with restricted movement for 3 months, and those in the other group could move normally. After 3 months, both groups of animals were put in the same inhalation chamber with a specific SO_2 concentration, where they remained on the same regimens of mobility. Determination was made of parameters inherent in the toxic effect of SO_2 in accordance with the tested concentration on the 1st, 3d, 5th, 7th, 10th, 12th, 15th, 20th, 30th, 45th, 60th and 90th experimental days. The 9th and 10th groups of animals served as an additional control. The 9th group was allowed normal motor activity and breathed pure air, the 10th also had pure air but was confined to hypokinetic conditions.

In the experiments dealing with investigation of the "concentration-effect" function (second series), the animals were submitted to hypokinesia throughout the experiment and around the clock inhalation of SO_2 (concentrations of 0.05, 0.5, 2.0 and 5.0 mg/m^3; 1st-4th groups). The 5th and 6th groups of rats served as a control and were kept in clean air with unrestricted movement and under hypokinetic conditions, respectively.

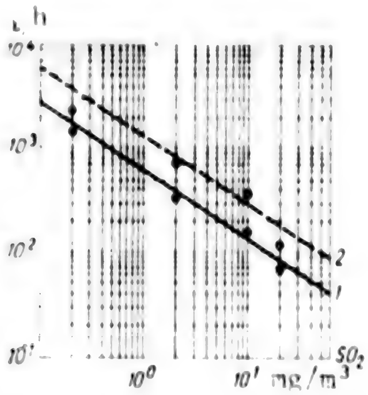
Results and Discussion

At the start of the studies, determination was made of the time in which hypokinesia led to marked pathological changes ($P<0.05$). By means of specific parameters, determination was made of the pathology in the presence of which the effect of SO_2 would be tested. Marked systemic changes were demonstrable in animals at the end of the 3d month of hypokinesia, and they were indicative of onset of a generalized pathological state. Overall gas exchange (according to O_2 uptake) increased by 24%, as compared to the control, body weight dropped by 36%, static endurance of the animals diminished to one-fifth, immunobiological reactivity decreased, Ca content of blood increased by 23% and elimination thereof in urine doubled, which is related to migration of Ca from the main reservoir as a result of diminished load on the skeletal system.

The results of this study revealed that there was a definite relationship between concentration of gas and time of onset of toxic effects in both "healthy" and "weakened" animals.* The role of the time factor in development of SO_2 poisoning is well-confirmed by the results of dynamic studies of blood pyruvic acid, erythrocyte transketolase activity, quantity of blood sulfhydryl groups and other parameters. As the concentration of SO_2 in air diminished, there was an increase in time of appearance of statistically reliable changes (see Figure), and they were used as the criterion of appearance of a toxic effect. When "weakened" animals were exposed to the same concentrations of SO_2, we demonstrated the same pattern, but changes occurred considerably sooner in

*Animals submitted to prolonged hypokinesia and SO_2 inhalation are referred to as "weakened," and those allowed normal motor activity as "healthy."

animals submitted to prolonged hypokinesia. Thus, statisticall reliable changes in pyruvic acid content occurred in 168 h after exposure to SO_2 in a concentration of 20.0 mg/m^3 in "healthy" animals and in 24 h in "weakened" ones; with use of a concentration of 2.0 mg/m^3, they occurred after 720 and 360 h, respectively. In "weakened" animals exposed to SO_2 in a concentration of 20.0 mg/m^3, a statistically significant decrease in erythrocyte transketolase activity to 1.5±0.2 units (versus 3.7± 0.4 units in the control) occurred in 72 h and with a concentration of 2.0 mg/m^3 after 360 h; in "healthy" animals such changes were demonstrated only after 120 and 720 h, respectively.



Time of appearance of toxic effect as a function of SO_2 concentration in air

1, 2) changes in erythrocyte transketolase activity in weakened and healthy animals, respectively ($P<0.05$)

Reduction to 1/2-1/5 in time of occurrence of the effect in "weakened" animals was also demonstrable according to changes in other parameters (in quantity of blood SH groups, leukocytes, protein and protein fractions in blood serum, eosinophils). We observed unidirectional changes with all concentrations used, as well as a distinct dependence of severity of changes on reactivity of the animals. Thus, with all concentrations of SO_2, it elicited a statistically reliable change in total leukocyte count and absolute eosinophil count in weakened animals by the end of the experiment. With 20.0 mg/m^3 SO_2, total leukocyte count constituted 6800±500 (versus 11,300±1300 in the control) and absolute eosinophil count was 97.3±21.9 (versus 192.5±14.5), which could be attributed to depression of immunobiological reactivity.

Examination of general exchange of gases (according to O_2 uptake by the method of indirect calorimetry using a Spirolit instrument) revealed that with prolonged exposure to SO_2 in a concentration of 0.2 mg/m^3 there was 15% depression of general gas exchange in healthy animals and 28% depression in weakened ones.

The nature and severity of changes demonstrated in experimental animals confirm the fact that the "concentration-time" function is a reflection of general patterns of effects of atmospheric pollutants on both the healthy and weakened organism. Time of onset of the toxic effect, taking into consideration changes in all of the above-mentioned parameters, decreased to about 1/5th in animals with diminished constitutional resistance. Approximation of the obtained data on a grid with a logarithmic scale enabled us to define the toxicometric parameters for "healthy" and "weakened" animals (see Table). Threshold concentrations for weakened and healthy animals were determined from the direct "concentration-time" functions. Thus, concentrations of 0.2 mg/m^3 were biologically equivalent in threshold of chronic effect according to change in pyruvic acid for weakened animals and 0.4 mg/m^3 for healthy ones; the figures were 0.09 and 0.24 mg/m^3 according to change in erythrocyte transketolase activity. These data indicate that animals submitted to hypokinesia are 2-3 times more sensitive to SO_2 than rats whose motor activity was normal. The same pattern was noted with regard to levels of ineffective

concentrations. Here, there was a 2-4-fold difference between parameters for weakened and healthy animals.

Quantitative evaluation of effects of different concentrations of SO_2 on weakened and healthy animals

ANIMAL GROUP	HOUR OF ONSET OF EFFECT AT DIFFERENT SO_2 CONC., MG/M^3				ESTIMATED THRESH. CONCENTRATIONS OF SO_2, MG/M^3				ESTIMATED INEFFECTIVE CONCENTR. OF SO_2, MG/M^3		
	20.0	10.0	2.0	0.2	1 MO	2 MOS	3 MOS	4 MOS	PER YEAR	PER MONTH	PER DAY
	ACCORDING TO BLOOD PYRUVIC ACID CONTENT (138° ANGLE OF CURVE, RESERVE COEFFICIENT 5)										
NORMAL MOTOR ACTIVITY	168	288	720	2160	2,0	0,92	0,58	0,4	0,08	0,12	0,32
HYPOKINESIA	24	168	360	1440	0,8	0,42	0,28	0,2	0,04	0,06	0,16
	ACCORDING TO ERYTHROCYTE TRANSKETOLASE ACTIVITY (147° ANGLE OF CURVE, RESERVE COEFFICIENT 10)										
NORMAL MOTOR ACTIVITY	120	360	720	2160	1,9	0,7	0,34	0,24	0,024	0,036	0,096
HYPOKINESIA	72	168	360	1440	0,78	0,28	0,14	0,9	0,009	0,013	0,036
	1,7	2,1	2,0	1,5	2,4	2,5	2,4	2,7	2,7	2,7	2,7
	ACCORDING TO BLOOD SH GROUP CONTENT (145° ANGLE OF CURVE, RESERVE COEFFICIENT 8)										
NORMAL MOTOR ACTIVITY	168	288	1080	2160	2,0	0,8	0,45·	0,3	0,04	0,06	0,16
HYPOKINESIA	72	168	480	1080	0,6	0,25	0,15	0,09	0,01	0,015	0,04
MULTIPLICITY OF DIFFERENCE	2,4	1,7	2,2	2,0	3,3	3,2	3,0	3,3	4,0	4,0	4,0

The results of the second series of experiments revealed that the severity of pathological changes depends on the concentration of the factor used. Thus, a reliable change in leukocyte count was noted with exposure to SO_2 in concentrations of 0.5, 2.0 and 5.0 mg/m^3; the discreteness of changes constituted 23, 78 and 173%, respectively. This function was also confirmed by the data on change in blood pyruvic acid. By the end of the experiment, pyruvic acid content of blood constituted 1.8±0.13, 2.0±0.10, 2.3±0.05 and 2.8±0.08 mg% with concentrations of 0.05, 0.5, 2.0 and 5.0 mg/m^3, respectively (versus 1.8±0.05 mg% in the control). The curves plotted on the bases of graded parameters for transketolase of erythrocytes and the phagocytic index revealed an analogous pattern. The same quantitative function was demonstrable (which is particularly important) when alternative parameters of presence of 25% deviations, as compared to the same parameters for control animals, were used as a criterion. Thus, it is possible to express the probability of onset of pathological changes as a function of concentration of exposure factors, and this could serve as the basis for approximate forecasting of adverse changes under the effect of toxic agents.

Quantitative evaluation of the effect on animals of different concentrations of SO_2 on the basis of studying the "concentration-time" function enabled us to establish that the toxic effect of SO_2 is manifested 2.5 times faster in animals submitted to prolonged hypokinesia than animals with normal motor activity.

Quantitative evaluation of the effect of different concentrations of SO_2 on the basis of studying the "concentration-effect' curve revealed that the toxic effect of SO_2 is manifested in hypokinetic rats in concentrations that are 1/2-1/4 of the concentrations to which animals with normal motor activity are exposed.

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NYSTAGMIC REACTIONS OF RATS AFTER FLIGHT ABOARD COSMOS-1129 BIOSATELLITE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 6, Nov-Dec 82 (manuscript received 25 Jan 82) pp 45-48

[Article by A. A. Shipov and L. A. Tabakova]

[English abstract from source] The vestibular nystagmus of rats flown for 18.5 days on Cosmos-1129 was examined with reference to the latent period, number of beats, duration and the average velocity. The nystagmus was elicited by increasing angular acceleration of 10, 20, 30°/sec^2. As compared to the controls, the flown animals showed a significant inhibition of the nystagmic reaction ($P<0.001$). The inhibition can be attributed to the desynchronosis which developed inflight.

[Text] In the experiment aboard Cosmos-936 biosatellite, rats flown for 18.5 days in weightlessness failed to demonstrate differences in the recovery period in nystagmic reactions, as compared to animals in ground-based control experiments. On this basis, it was concluded that there is no change in function of semicircular canals as an aftereffect of weightlessness [1].

The main objective of the experiment aboard Cosmos-1129 was to conduct biorhythmological studies, which involved different conditions with respect to illumination from previous experiments [2]. It was interesting to find out the extent of resistance of a parameter of vestibular function such as the nystagmic reflex to such changes in ambient conditions.

Methods

The study was conducted on 15 male white Wistar SPF rats initially weighing 210-250 g. The animals were divided into 3 equal groups: the 1st consisted of rats flown in space for 18.5 days, the 2d of animals used in a ground-based synchronous experiment and the 3d, vivarium control rats.

All groups of animals were exposed to equal periods of light and darkness (12:12) starting 1 month before the flight and ending when postflight studies were completed.

During the first half of the flight, the phase of the photoperiod of the onboard schedule of illumination coincided with the same phase for the

initial (ground-based) upkeep conditions. On the 10th flight day the phases were inverted. The distribution of light and darkness during the second half of the flight in astronomic days was retained for the entire postflight period. Analogous conditions were created for animals in the synchronous experiment and vivarium control.

The animals were examined at times corresponding to the astronomical daytime.

We examined the characteristics of vestibular nystagmus, which the animals presented in response to a series of ascending angular accelerations (10, 20 and $30°/s^2$) with the animal's head in the center of rotation. The platform with the animal was then shifted 15 cm forward along the longitudinal axis of the body and they were examined during 3-fold eccentric rotation at angular acceleration of $30°/s^2$ (centrifugal acceleration constituted 0.04 G), after which the platform was returned to its original position and the test continued with acceleration of $30°/s^2$.

The rotation was effected on a trapezoid program: positive acceleration lasted 3 s--rotation at constant velocity for 1 min--negative acceleration. With each successive acceleration, the direction of rotation was reversed. There were 1.5-2-min intervals between two successive rotations.

Nystagmus was evaluated on the basis of its latency period (from time mark of start of rotation to start of rapid phase of first nystgamic beat), number of beats, duration and mean frequency (quotient from dividing the number of beats by duration of nystagmus).

The animals were examined 4 weeks before the flight and start of ground-based control experiments, as well as on the 1st, 6th, 11th and 21st days of the recovery period.

After concluding the experiments, we conducted an additional control series of tests on two groups of Wistar rats (10 in each group), with one-time recording of nystagmus during astronomic daytime and night time.

The results were submitted to statistical processing with use of Student's criterion ($P<0.05$).

Results and Discussion

We failed to demonstrate reliable differences in characteristics of nystagmus in rats of the vivarium control and synchronous experiment at any time. When they were rechecked, we observed changes in the reaction that were indicative of development of habituation to angular accelerations (Figure 1).

Rats flown in space showed an increase in latency period on the 1st postflight day, with drastic decrease in number of beats, duration and frequency of nystagmus, as compared to values recorded for control groups of animals ($P<0.001$). In subsequent examinations, the nystagmic reaction remained diminished in animals flown in space.

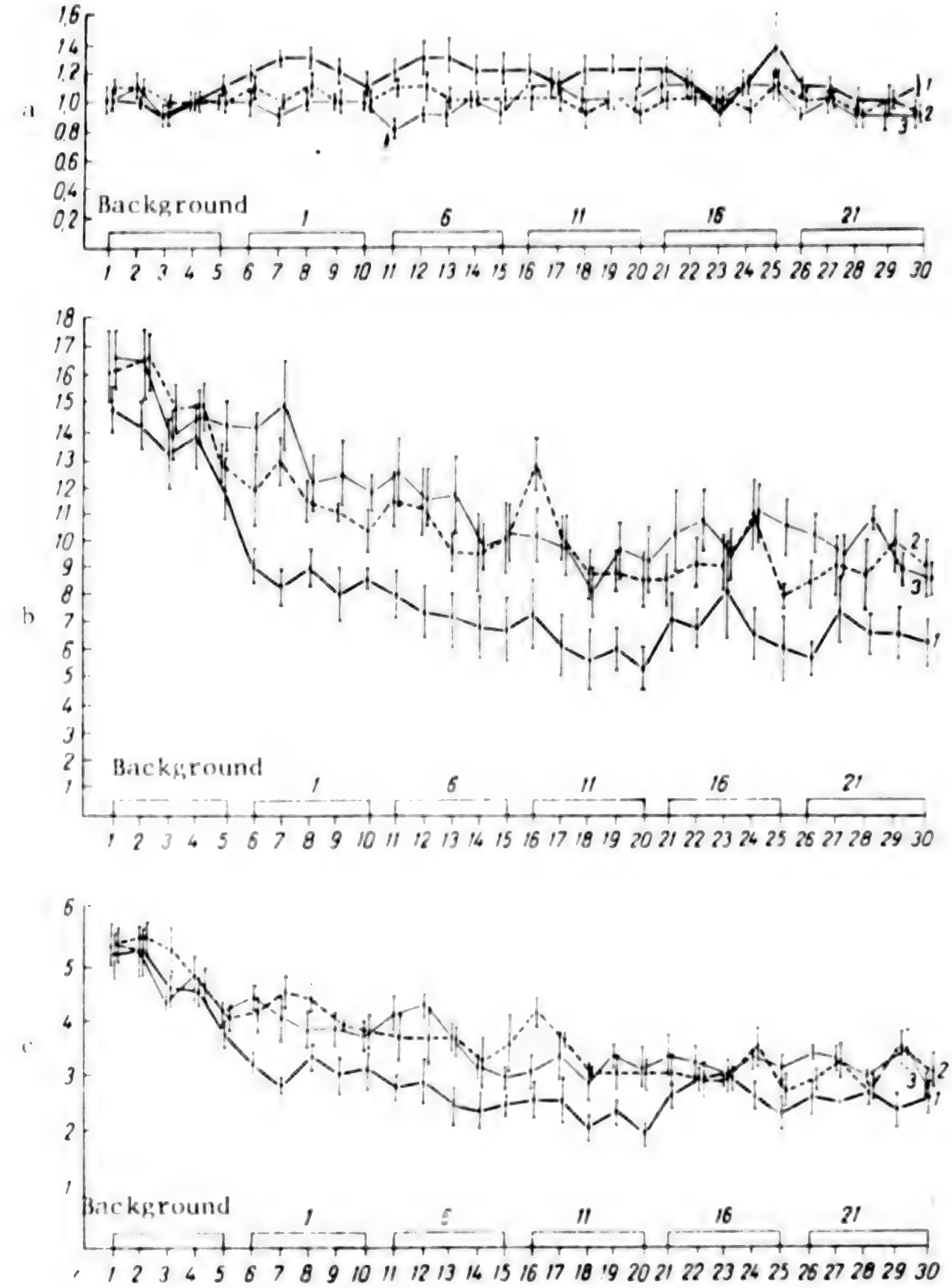

Figure 1. Latency period (a; in seconds), number of beats (b) and duration of nystagmus (c; in s) in rats during recovery period after 18.5-day flight aboard Cosmos-1129

1,2,3) animal groups (flight, synchronous experiment and vivarium control, respectively). In all cases angular acceleration was $30°/s^2$. X-axis, numbers at top--day of examination, bottom--sequential number of rotation.

Previously, in the experiment aboard Cosmos-936, no differences were noted in nystagmic reactions of rats flown in space for 18.5 days and those used in ground-based control experiments [1] throughout the postflight period. There was particularly vivid demonstration of differences between the two experiments when we compared the nystagmic reactions of flight groups of animals (Figure 2a).

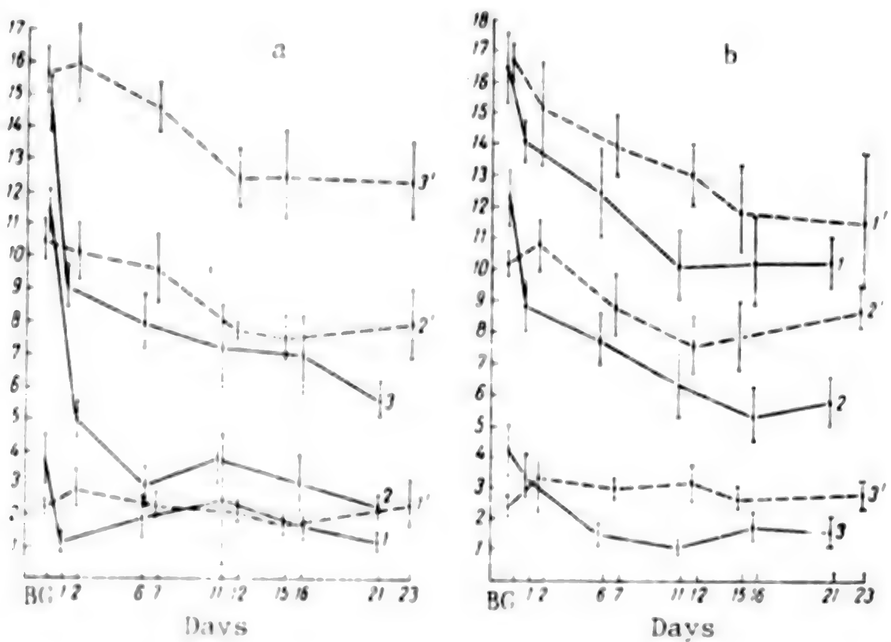

Figure 2. Comparison of dynamics of nystagmus beats in flight groups (a) and vivarium control (b) animals in experiments aboard Cosmos-1129 (solid lines) and Cosmos-936 (dash lines)

1-3) angular accelerations of 10, 20 and 30°/s², respectively.

X-axis, day of study.

The inversion of daylight mode was the distinction of the experimental conditions aboard Cosmos-1129, and for this reason postflight studies of the animals were conducted during the period of night time for them. When recording nystagmus at night, according to the comparison of reactions of vivarium (and synchronous) groups in both experiments (Figure 2b), we could have expected lower values for such parameters as number of beats, duration and frequency of nystagmus. This was confirmed in a special control series of studies. But this finding does not explain the profound depression of nystagmus in the flight group of animals in the experiment aboard Cosmos-1129, since the control groups were also examined at the period of night for them.

The results of biorhythmological studies conducted aboard Cosmos-1129 revealed that exposure of animals to weightlessness in individual cages [units] and subsequent effect on them of the set of tests with inversion of daylight hours led to development of persistent desynchronosis, which persisted throughout the period of postflight studies [2]. In our opinion, the profound depression of the nystagmic reflex in animals flown in space is related expressly to presence of desynchronosis.

Depression of the nystagmic reflex in rats at night (time of maximum activity in rats), as well as in the presence of desynchronosis, is probably mediated by the cerebral cortex [3].

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FLUID-ELECTROLYTE METABOLISM IN RATS IN DIFFERENT POSITIONS IN RELATION TO VECTOR OF EARTH'S GRAVITY

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 6, Nov-Dec 82 (manuscript received 15 Oct 81) pp 48-50

[Article by V.I. Bogdanov, V. P. Krotov and L. Ya. Kolemeyeva (deceased)]

[English abstract from source] A prolonged maintenance of rats with the long axis of the body positioned at +15° or -15° to the horizontal influenced their fluid-electrolyte metabolism. The experiments were carried out on 56 noninbred rats whose motor activity was diminished for 32 days. A close correlation between fluid-electrolyte metabolism and body position was established. As compared to the horizontal rats, the rats with the head at +15° showed decreases in body weight losses, diuresis, kali- and natriuresis, whereas the rats with the head at -15° exhibited in-increases of the parameters.

[Text] It is known that significant shift of fluid in the body (for example, when submerging in water) elicits a drastic increase in diuresis and excretion of electrolytes in urine [1, 2]. In some cases, the fluid and electrolyte balance becomes negative.

When man changes from erect to horizontal position and remains in the latter position for some time, this also leads to increased elimination of fluid and electrolytes, although to a lesser extent than immersion [3-5].

At the same time, there are very few works in the literature concerning fluid-electrolyte metabolism when the long axis of the body is deflected by several degrees from the horizontal with strictly measured or constant fluid and salt intake [6].

Our objective here was to investigate the effect on rats of prolonged ±15° deflection of the longitudinal axis of the body from the horizontal plane with regard to parameters of fluid-electrolyte metabolism.

Methods

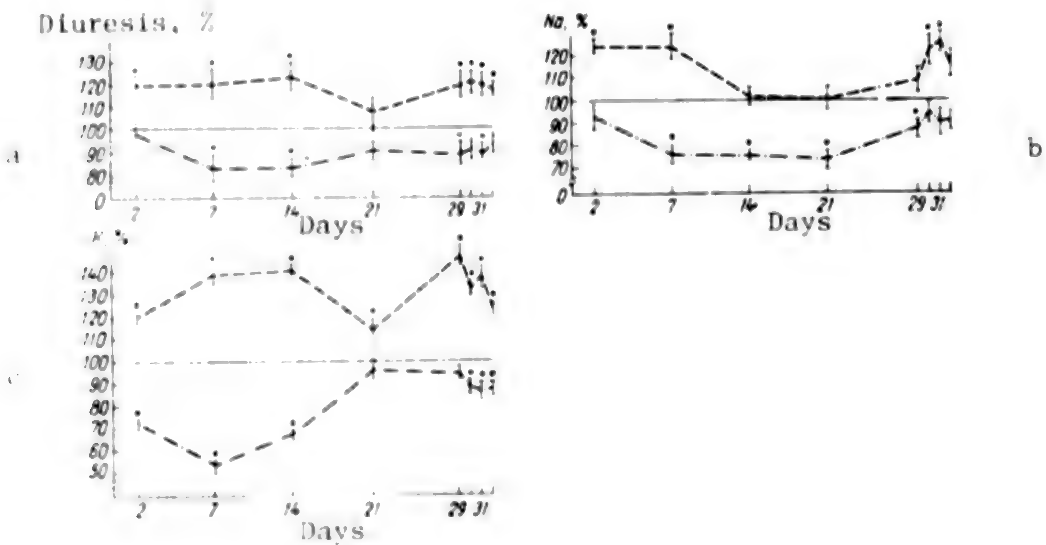
Experiments were conducted on 56 noninbred rats weighing 200-220 g. The animals were divided into 4 groups of 14 rats. The first group of rats was put in

individual metabolic cages: the 2d-4th groups were restricted in their movements: 2d group consisted of animals kept in horizontal position, 3d--head end of cage was raised 15° from the horizontal plane and 4th--head end was dropped 15°. The experiment lasted 32 days. The daily food allowance for rats consisted of feed with the consistency of jello containing 15 g ground pellet feed, 30 mℓ water and 2.0 g starch. Salt was added at the rate of 0.4 g/100 g body weight. The animals were weighed and 24-h urine collected on the 2d, 7th, 14th, 21st, 28th-32d days of the experiment. Sodium and potassium content of urine was assayed by flame photometry.

The results were submitted to variation statistical processing according to Student.

Results and Discussion

From the 7th day to the end of the experiment, the 2d group of rats weighed 12-29% less ($P<0.05$) than the 1st group. At the same time, the 3d group of rats weighed 3% more than the 2d group ($P<0.05$) from the 14th day to the end of the experiment, whereas the 4th group, on the contrary, lost weight, and this was particularly marked from the 29th to 32d days--4% ($P<0.05$).



Dynamics of diuresis (a), natriuresis (b) and kaliuresis (c) in hypokinetic rats as related to body position in relation to horizontal plane (%). Solid lines--clinostatic hypokinesia; dash-dot lines--orthostatic hypokinesia (+15° angle) and dash lines--antiorthostatic hypokinesia (-15° angle); asterisk shows reliable differences, as compared to parameters during clinostatic hypokinesia

Restriction of animal mobility elicited an increase in diuresis over the entire observation period. However, it was greater in the 4th group and lesser in the 3d group than in the 2d group of animals. When diuresis was scaled to the unit of body weight, the direction of changes was more marked. In all animals of the 2d group, diuresis increased by 20% on the 2d day, 32 and 50%

on the 7th and 14th days, respectively, whereas it almost doubled between the 21st and 32d days (in all cases, P<0.02).

In the third group of animals, the decline of diuresis reached 17% ($P<0.02$) on the 7th and 14th days, 11% on the 29th and 31st days ($P<0.05$), whereas an increase was demonstrated in the 4th group by an average of 19% ($P<0.02$) on the 2d, 7th, 14th, 29th-32d days, as compared to the 2d group (see Figure).

It should be noted that the changes in weight and diuresis as a function of body position in relation to the horizontal plane were not only in the same direction, but virtually identical. Thus, when there was weight loss of 6 g (3% of 200 g) diuresis increased by 4-5 mℓ (20% of base level of diuresis, 20-25 mℓ). Considering that fluid intake was the same in all groups of animals, the changes in diuresis in different directions were indicative of a relationship between fluid content in the rats and their position in relation to the vector of earth's gravity. An analogous relationship was found in people kept on bed rest, with +6° deflection of the longitudinal axis of the body from the horizontal line. The body position in space did not affect extrarenal loss of fluid, the degree of which diminished significantly in all subjects [7].

Excretion of potassium and sodium in urine increased by a mean of 25% in the 2d group of animals and, with consideration of change in body weight, by 1.5 times, as compared to the 1st group of animals. In the 4th group, there was an increase in excretion of electrolytes in urine: by an average of 32% ($P<0.01$) for potassium and 22% ($P<0.05$) for sodium on the 7th and 30th-32d days. Kaliuresis and natriuresis diminished in the 3d group of animals, as compared to the 2d group: by an average of 36% ($P<0.001$) on the 2d, 7th and 14th days, average of 11% ($P<0.02$) on the 30th-32d day for potassium excretion; mean of 24% ($P<0.01$) on the 7th, 14th and 21st days, 12% ($P<0.05$) on the 29th day for sodium excretion. Consequently, deflection of the body from the horizontal plane by +15° affects excretion of electrolytes in urine, particularly kaliuresis.

Recent studies have shown that movement of people in space in the range of -6° to +15° from the horizontal plane causes changes in concentration of antidiurectic hormone, aldosterone and renin activity in blood by 1.5-2 times [8, 9]. Even this insignificant deflection of the body from the horizontal plane affects the function of the adrenosympathetic system, concentration of serotonin and histamine in blood [10]. At the same time, it is known that both serotonin and histamine, which act upon the anterior hypothalamic nuclei via the acetylcholine-cholinesterase system, increase secretion of antidiuretic hormone [11]. The changes in different directions referable to fluid-electrolyte metabolism, which we observed, are the result of different reactions of the neuroendocrine system to insignificant deflections of the body.

Thus, shifting of body fluids due to change in spatial position of the body, which affects the receptors of volume regulating and osmoregulating systems, has a distinct influence on total amount of fluid and electrolytes. We consider it important that this is observed not only in people whose volume-regulating and osmoregulating systems are conditioned by means of daily postural changes, but in animals with predominantly horizontal body position, i.e., apparently it is a universal phenomenon.

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EFFECT OF DRUGS ON DEVELOPMENT OF STRESS REACTION IN RATS EXPOSED TO ACOUSTIC STIMULUS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 6, Nov-Dec 82 (manuscript received 21 Dec 81) pp 50-54

[Article by V. N. Kostyuchenkov and V. S. Yasnetsov]

[English abstract from source] The experiments were carried out on 349 white rats weighing 150-200 g that were exposed to the stress effect of 130 dB sound. Drugs were injected subcutaneously an hour before the animals were placed into a sound chamber. In this situation the following drugs proved to be the most effective sound protectors: barbamyl, seduxen, aminazin, galoperidol, chloroprotixen, apressin, phentolamine, inderal and dopegyt.

[Text] In this age of intensive technological progress, noise control is one of the most pressing problems of modern medicine. The noise load on the central nervous system is the cause of many diseases [1-3]. For this reason, the search for drugs that would prevent or attenuate the body's pathological reactions to acoustic stimuli is warranted from the practical and theoretical points of view. Our objective was to track the changes developing in animals under the effect of sound and investigate the effect of pharmacological agents on development of the stress reaction.

Methods

This study was conducted on 349 white rats of both sexes weighing 120-200 g. One rat at a time was placed in a sound chamber. Acoustic stress was induced by a 130 dB sound. After the animals developed seizures, the bell was turned off. If the pharmacological agents prevented development of seizures, exposure to the sound was continued for 5 min. We determined the weight of the adrenals, thymus and presence of hemorrhages in the gastric mucosa 24 h after exposure to the acoustic stimulus.

We tested the following pharmacological agents: soporifics (barbamyl, chloral hydrate), neuroleptics (aminazin [chlorpromazine], haloperidol, reserpine, chlorprothixene), tranquilizers (seduxen [Hungary]), central cholinolytics (amizil [benactyzine hydrochloride], spasmolytin), antidepressants (teperin, nuredal [nialamide], sapilent), adrenoblocking agents (apressin, inderal, phentolamine), sympathoblocking agents (gemidin [hemidin?], Yegit-739, guanethidine, dopegyt [methyldopa, aldomet]), ganglioblocking agents

(benzohexonium), M-cholinolytics (atropine), catecholamines (epinephrine, L-dopa, serotonin), adaptogens (dibazol) and eleuterococcus. Saline was used as placebo. All of the tested agents were injected subcutaneously 1 h before the acoustic stimulus. The results are listed in the Table.

Effect of drugs on animals exposed to noise

ANIMALS AND DRUGS	DOSE, MG/KG	NUMBER OF ANIMALS	SEIZURES %	WEIGHT OF ADRENALS		WEIGHT OF THYMUS		QUANTITY OF HEMORRHAGES IN GASTRIC MUCOSA	
				M ± m	P	M ± m	P	M ± m	P
INTACT ANIMALS	—	10	—	40±1,07	—	117,7±1,46	—	0	—
AFTER EXPOSURE TO ACOUSTIC STIMULUS	-	30	100	50,5±1,67	<0,001	98,2±2,58	<0,001	4,8±0,8	
SALINE	1ML	29	100	53,2±2,2	<0,001	97,4±2.57	<0,001	4,6±0,8	>0,5
BARBAMYL	5	10	0	43,4±1,0	>0,05	118,5±3,9	>0,5	0±0	<0,001
CHLORAL HYDRATE	5	10	80	48,5±1,47	<0,001	107,6±3,45	>0,05	4,2±1,1	>0,5
AMINAZIN	5	15	10	43,9±1,17	>0,05	120,0±2,43	>0,5	0	<0,001
HALOPERIDOL	5	10	10	46,7±2,20	<0,05	113,9±2,7	>0,1	0,3±0,1	<0,001
CHLORPORTHIXENE	5	10	20	45,9±1,3	≤0,05	120,2±4,59	>0,5	2,4±0,9	<0,01
RESERPINE	5	10	70	50,4±2,10	<0,01	103,2±3,6	<0,05	6,0±1,3	>0,1
SEDUXEN	5	15	0	43,8±1,2	>0,05	124,7±1,77	>0,1	0	<0,001
AMIZIL	5	10	40	48,0±1,58	<0,05	110,6±2,83	>0,05	2,2±0,6	<0,01
SPASMOLYTIN	5	10	80	48,7±0,97	<0,05	108,4±4,26	>0,05	4,5±0,9	>0,5
SEROTONIN	5	10	100	51,3±1,46	<0,001	107,2±4,4	<0,05	4,9±1,0	>0,5
L-DOPA	100	10	90	54,5±1,51	<0,001	90,5±2,96	<0,001	4,9±1,1	>0,5
EPINEPHRINE	0,5	10	90	51,4±2,38	<0,001	106,9±5,24	<0,05	6,7±1,27	>0,05
TEPERIN	10	10	70	48,4±1.59	<0,001	110,1±3,69	>0,1	4,0±1,0	>0,5
NUREDAL	10	10	90	51,1±2,24	<0,001	105,6±3,8	<0,05	4,7±0,9	>0,5
SAPILENT	10	10	60	50,4±1,74	<0,001	107,8±5,58	>0,1	4,1±0,8	>0,5
APRESSIN	5	15	20	47,9±0,85	<0,001	114,2±3,42	>0,5	0,5±0,3	<0,001
PHENTOLAMINE	10	10	30	45,5±0,96	<0,05	115,5±4,8	>0,05	1,2±0,6	<0,01
INDERAL	5	10	30	46,7±1,58	<0,05	118,7±4,0	>0,5	2,1±0,9	<0,01
DOPEGYT	100	15	10	44,4±1,37	<0,05	121,1±3,98	>0,5	0,6±0,1	<0,01
GUANETHIDINE	10	10	60	48,3±2,08	<0,01	107,5±5,58	>0,05	3,7±1,3	<0,05
GEMIDIN	10	10	50	49,3±2,34	<0,01	112,6±4,81	>0,5	1,8±0,6	<0,01
YEGIT-739	10	10	40	50,8±3,06	<0,05	110,5±4,34	>0,1	2,9±0,9	<0,05
BENZOHEXONIUM	5	10	20	46,9±2,26	<0,05	114,7±3,48	>0,5	1,2±0.5	<0,01
ATROPINE	5	10	100	52,6±2,07	<0,001	101,0±3,64	<0,001	5,1±1,2	>0,5
DIBAZOL	10	10	90	51,3±1,75	<0,01	109,8±2,8	<0,05	4,9±1,0	>0,5
ELEUTEROCOCCUS	1ML	10	100	53,3±2,7	<0,001	102,0±2,59	<0,01	5,3±1,2	>0,5

Note: P is given in comparison to control.

Results and Discussion

In all control animals, the acoustic stimulus elicited generalized motor excitation within 5-10 s, which was replaced with seizures after 1 min (1±0.08). The rats fell on their side presenting severe clonic seizures, which changed into tonic contraction of all muscles in some animals. The animals gradually recovered after the bell was turned off (within 5-10 min). After 1 day, there was 26.2% increase in weight of the adrenals and 15.8% decrease in weight of the thymus. The gastric mucosa showed petechial hemorrhages. Our findings are consistent with data in the literature [4, 5]. Thus, a stress state characterized by the triad of Selye developed under the influence of acoustic stimulation.

The pharmacological agents had different effects on development of pathological processes in response to acoustic stimulation. Thus, chloral hydrate, which depresses primarily the cerebral cortex, did not prevent development of pathological processes. Barbamyl, which acts mainly on the brain stem, prevented seizures, dystrophy of the gastric mucosa and change in adrenal and thymus weight in 100% of the cases. The tranquilizer, seduxen, had the same effect. Consequently, depression of subcortical structures prevents development of stress reactions to an acoustic stimulus.

Contradictory opinions are voiced in the literature concerning the effect of the neuroleptic agent, aminazin. According to the data of A. Ye. Aleksandrova [6], aminazin has no appreciable protective effect against development of dystrophic lesions under stress. However, O. N. Zabrodin [7], Bonta [8] and several other authors reported a marked protective effect of aminazin with regard to various extreme states. In our tests, aminazin prevented seizures in 99% of the cases and prevented dystrophic changes in the gastric mucosa in 100% of the experiments. There was no appreciable change in weight of the adrenals or thymus, as compared to intact rats. The neuroleptics, haloperidol and chlorprothixene, had an analogous effect. Reserpine prevented seizures in 3 out of 10 experiments. This agent had no appreciable effect on development of dystrophic lesions in the stomach or weight of the adrenals and thymus.

It is known that aminazin blocks α-adrenoreactive systems of the reticular formation. Haloperidol and chlorprothixene have some adrenolytic effect. Reserpine has sympatholytic action; it depletes the reserves of catecholamines in endings of adrenergic nerves and its action is slow [2, 9, 10]. For this reason, when given 1 h before acoustic stimulation, reserpine does not have time to elicit an effect. It can be assumed that central adrenoreactive structures are involved in development of pathological processes under the effect of an acoustic stimulus. and the protective effect of neuroleptics is related to their blocking. This is also confirmed indirectly by the fact that appressin has diverse effects, including adrenolytic [9, 11]]; it affects development of the stress reaction analogously to aminazin and haloperidol. Preliminary administration of catecholamines (epinephrine, L-dopa) and serotonin had no effect on development of pathological processes.

Experiments with amizil and spasmolytin were performed to determine whether central cholinergic structures are involved in development of the adaptation syndrome. According to some authors, amizil protected the gastric mucosa against reflex dystrophies [2, 12-14]. The results of our experiments indicated that amizil prevented seizures and reduced the quantity of petechia in the gastric mucosa with statistical reliability in 6 experiments. However, this effect was much weaker than that of central α-adrenoblocking agents. Spasmolytin had no effect on development of pathological processes under extreme conditions. It can be assumed that the protective effect of amizil is related to blocking of central M-cholinoreactive structures. N-cholinoblocking agents had no effect on development of seizures or formation of reflex ulcers in the gastric wall.

Testing of antidepressants revealed that nuredal, teperin and sapilent had no appreciable effect on development of the stress reaction.

Experiments with ganglioblocking agents and mediators were conducted to determine the participation of the autonomic nervous system and peripheral synapses

in development of the stress reaction to acoustic stimulation. They revealed that benzohexonium prevented development of seizures in 80% of the cases and reduced, with statistical reliability, the quantity of hemorrhages in the gastric mucosa. Weight of the thymus did not, however, differ appreciably from that of intact animals.

The α-adrenoblocking agent, phentolamine, and β-adrenoblocking agent, inderal, prevented seizures in 70% of the cases, diminished the quantity of petechia in the gastric mucosa and altered the weight of the adrenals and thymus.

The sympathoblocking agent, dopegyt, prevented seizures in 9 out of 10 tests. This was associated with decrease in number of hemorrhages in the gastric mucosa to 0.6, from 4.8 in the control. There was no change in weight of the adrenals and thymus, as compared to intact animals. Other sympatholytics (guanethidine, gemidin, Yegit-739) had an anticonvulsive effect in 40-60% of the cases and diminished by 30-60% the number of lesions to the gastric mucosa.

The M-cholinolytic, atropine, had no effect on development of the stress reaction. Thus, on the basis of the above series of experiments, it can be concluded that the adrenosympathetic system, α- and β-adrenoreceptors are important to development of pathological states under extreme conditions caused by acoustic stimulation.

In the next series of experiments, we tested agents in the adaptogen group. As shown by our findings, dibazol and eleuterococcus given 1 h before exposure to sound were ineffective.

Our analysis covering a number of pharmacological agents indicates that seizures and dystrophic changes in the gastric mucosa, which appear under acoustic stress, are of reflex origin. The central and sympathetic nervous systems play a predominant role in formation of pathological reactions to strong acoustic stimuli. Barbamyl, seduxen, aminazin, haloperidol, chlorprothixene, apressin, phentolamine, inderal and dopegyt were found to be the most effective drugs for acoustic stress. These pharmacological agents can be recommended for furhter investigation in order to make good use of them as therapeutic and preventive agents with exposure to inadequate acoustic stimuli. Further investigations in this area would not only reveal the most effective agents for clinical use, but enable us to gain deeper understanding of pathophysiological, biochemical and morphological processes that develop under the effect of extreme factors.

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EVALUATION OF DEGREE OF GENETIC DETERMINATION OF HUMAN CARDIORESPIRATORY REACTIONS TO HYPOXIA AND HYPERCAPNIA

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 6, Nov-Dec 82 (manuscript received 11 Dec 81) pp 54-58

[Article by T. V. Serebrovskaya]

[English abstract from source] Using the twin method (16 pairs of monozygotic and 14 pairs of dizygotic twins), the role of the genotype and environment in the phenotypical variations of cardiorespiratory reactions to increasing hypoxia and hypercapnia was investigated. The process of emergency adaptation to acute hypoxia was shown to be associated with both genetically determined potentialities and acquired abilities. It is suggested that regular training may change sensitivity and emergency mechanisms of adaptation to hypoxia. However, the level of these changes depends on the individual genotype. The variability of hypercapnia sensitivity which is an individual genetically determined constant appears to be very low.

[Text] Man's endurance of extreme factors, in particular, acute hypoxia and hypercapnia, depends largely on individual reactivity of the body, speed of triggering and efficiency of mechanisms of critical ["emergency"] adaptation. Determination of the extent to which these individual differences are genetically determined and to what extent they are subject to the influence of environment and conditioning is of great theoretical and practical interest. One of the most promising means of answering this question is to study twins. The twin method is based on the possibility of comparing traits in two types of twins, monozygotic (MT), which are genetically identical, and dizygotic (DT), which have on the average only 50% genes in common [1]. A comparison of intrapair similarity of MT and DT makes it possible to assess the relative roles of genotype and environment in onset of interindividual reactions of the character under study. This article deals with investigation of the degree of genetic determination of human cardiorespiratory system reactions to progressive hypoxia and hypercapnia.

Methods

We studied 60 healthy young men 14-15 years of age, including 16 sets of MT and 14 sets of DT. Combined methods were used to identify dizygotic twins:

multisymptomatic method of similarity, serological analysis of blood groups in ABO, MN and Rh systems, special dermatoglyphic analysis, the method of odontoglyphics, portrait identification, gustatory test with phenylthiocarbamide. Prior clinical examination failed to demonstrate any deviations of health status.

Progressive hypoxia was produced by the method of rebreathing with absorption of CO_2 by soda lime beyond the air valve and progressive hypercapnia without CO_2 absorption, with initial gas mixture of 30% oxygen in nitrogen to rule out the combined effect of hypoxia and hypercapnia, which together have a multiplicative effect [2]. In order to standardize the rate of build-up of hypoxia and hypercapnia, the volume of initial gas mixtures in a confined space was batched for each pair of twins, on the basis of preliminary data concerning the parameters of exchange of gases for each subject. We monitored continuously pO_2 and pCO_2 of inhaled and alveolar air. We recorded minute volume of respiration ($\dot{V}_E$) and frequency of respiratory excursions (f). Stroke volume of the heart (Q_S) and heart rate (n) were determined by the rheographic method. Oxygen uptake ($\dot{V}_{O_2}$) and carbon dioxide output ($\dot{V}_{CO_2}$) were determined by the method of Douglas-Haldane; systolic and diastolic arterial pressure (P_s and P_d) were measured by the method of Korotkov. In addition to general statistical analysis, we calculated coefficients of intrapair correlation (r) based on analysis of intrapair variances of MT and DT, and Holzinger's genetic coefficient (H), which indicates the degree to which phenotypic diversity of a trait is genetically determined [3].

Results and Discussion

Investigation of respiratory and circulatory functions in twins at rest revealed that genotype and environment play a different role in phenotypic variability of different parameters. The intrapair differences in a number of parameters of MT were characterized by a considerably narrower range of variation than in DT, which is indicative of a high degree of their genotypic determination (Table 1). These parameters include, first of all (in order of decline of genetic [inheritance] coefficient), the following: partial tension of carbon dioxide and oxygen in alveoli, minute oxygen uptake (scaled to 1 kg body weight H = 0.96), rate of respiratory excursions, systolic pressure, minute volume of ventilation, stroke and minute volumes of circulation. At the same time, individual variability of parameters of minute output of carbon dioxide, heart rate, diastolic blood pressure depended more on the diversity of environmental influences. Some degree of hyperventilation at rest is attributable to the age of the subjects.

Examination of ventilation reaction to hypoxia and hypercapnia revealed that, with respect to both the "apnea point," which shows the threshold of sensitivity of the respiratory center to these stimuli [5, 6], and rate of build-up of ventilation, MT are characterized by greater coordination of reactions than DT (Table 2). At the same time, the data clearly indicate that the respiratory reaction to hypercapnia is genetically determined to a considerably greater extent than the reaction to hypoxia. The increase in ventilation with both hypoxia and hypercapnia occurred mainly due to increase in tidal volume (V_T; Figure 1). The frequency of respiratory excursions did not change with hypoxia, and with hypercapnia there was a tendency toward some increase. Interindividual differences in this parameter depended entirely on genetic factors.

Table 1. Degree of inheritance of main functional parameters of external respiration and hemodynamics of man at rest

GROUP OF SUBJECTS	STATIST. PARAMETER	$\dot{V}_E$, L/MIN	f, MIN^{-1}	V_T, ML	$\dot{V}_{O_2}$, ML/MIN	$\dot{V}_{CO_2}$, ML/MIN	p_AO_2, MM HG	p_ACO_2, MM HG	$\dot{Q}$, L/MIN	Q_s, ML	n, MIN^{-1}	P_s, MM HG	P_d, MM HG
MT	M	9,4	17,0	550	255	222	107,7	39,1	5,2	67	77	120	74
	±m	0,35	0,91	26,6	7,7	11,4	1,02	0,73	0,4	4,8	2,4	2,5	1,8
	r	0,81	0,90	0,86	0,85	0,68	0,93	0,98	0,87	0,91	0,69	0,89	0,82
DT	M	9,3	16,7	559	260	225	109,0	38,2	5,0	68	74	117	73
	±m	0,40	0,97	32,3	11,6	13,3	1,06	0,76	0,5	6,1	2,5	2,6	2,1
	r	0,02	0,12	0,41	0,38	0,45	0,23	0,23	0,37	0,62	0,39	0,36	0,50
	H	0,81	0,89	0,76	0,76	0,42	0,91	0,97	0,79	0,76	0,49	0,83	0,64

Table 2.
Values of ventilation response and apnea point in twins exposed to hypoxia and hypercapnia

GROUP OF SUBJECTS	STATISTICAL PARAMETER	HYPOXIA		HYPERCAPNIA	
		APNEA POINT, MM HG	$\dot{V}_E/pAO_2$	APNEA POINT, MM HG	$\dot{V}_E/pACO_2$
MT	M	109,1	0,47	33,4	2,41
	±m	1,86	0,06	1,13	0,35
	r	0,92	0,96	0,90	0,98
DT	M	108,5	0,44	32,0	2,24
	±m	2,25	0,04	1,10	0,26
	r	0,78	0,85	0,30	0,14
	H	0,64	0,73	0,86	0,98

In spite of significant increase in ventilation under hypoxic conditions, we observed gradual decline of oxygen uptake [7]. Carbon dioxide output increased, and this was all the more marked, the greater the degree of hypoxia (see Figure 1). Analysis of partial gas pressure and parameters of acid-base equilibrium of arterialized blood was indicative of the early stage of development of respiratory alkalosis (pH increase from 7.39±0.014 to 7.44±0.008; $paCO_2$ drop from 35.7±0.52 to 32.7±0.65 mm Hg and others). Such reactions have been described in the literature [2, 7 and others].

In MT, the initial phases of hypoxia were characterized by considerable individual variations in oxygen uptake, and intrapair variability diminished significantly only with a drastic degree of hypoxia; the genetic coefficient constituted 0.73. At the same time, individual differences in carbon dioxide output with hypoxia were found to depend exclusively on environmental factors (H = 0.19).

Opposite changes in gas-exchange parameters were observed with hypercapnia (Figure 1b). Oxygen uptake increased, which is attributable to partial replacement of nitrogen in pulmonary spaces with oxygen and other changes when using breathing mixtures with up to 30% enrichment [7]. There was drastic decrease in carbon dioxide: so-called "locking" of endogenous carbon dioxide by carbon dioxide in the respiratory mixture occurred [2]. The genetic coefficient constituted 0.40 according to oxygen uptake. At the same time, inter-individual variation of decrease in CO_2 output with hypercapnia was found to be strongly dependent on genetic factors (H = 0.87). The nature of changes in acid-base parameters of blood was also genetically determined to a significant extent: H = 0.68 for pH with hypercapnia, H = 0.72 for buffer base deficiency and H = 0.90 for standard bicarbonate.

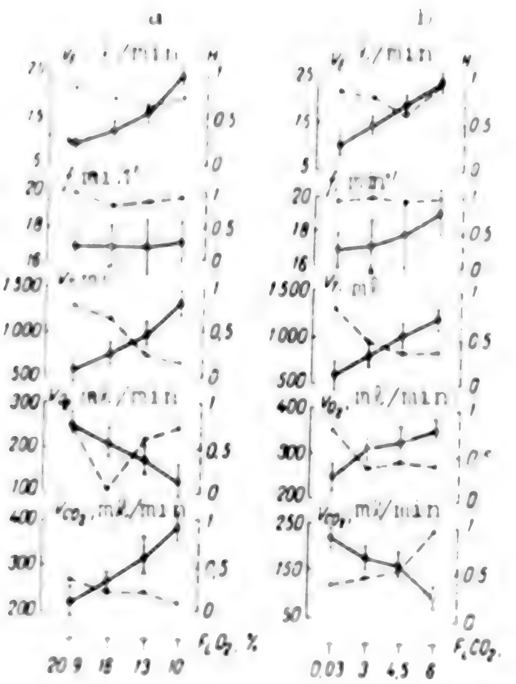

Figure 1.
Changes in parameters of external respiration and exchange of gases in twins with progressive hypoxia (a) and hypercapnia (b)

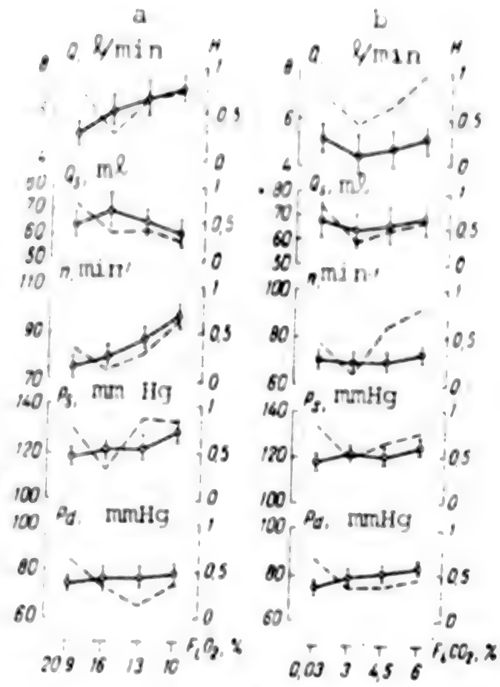

Figure 2.
Changes in hemodynamic parameters of twins with progressive hypoxia (a) and hypercapnia (b)

In both figures the dash line indicates changes in genetic coefficient.

The reactions of the circulatory system to hypoxia and hypercapnia were also largely dependent on the genotype. Minute circulation volume increased by 1.1±0.06 ℓ with hypoxia due to faster heart rate; stroke volume decreased by 13% (Figure 2a). Systolic blood pressure rose from 120±2.5 to 130±3.6 mm Hg; average diastolic pressure did not change appreciably. Such reactions to acute hypoxia have been described in both animals and man [8-11 and others].

Analysis of intrapair similarity of hemodynamic reactions of twins revealed that there was considerable variability of changes in all parameters studied at the early phases of hypoxia; the coefficients of inheritance were characterized by low values for different parameters. With considerable hypoxia (paO_2 constituted 34-36 mm Hg), the effect of the genotype was evident on such parameters as minute volume of circulation (H = 0.67), heart rate (H = 0.71) and systolic blood pressure (H = 0.78). Stroke volume was determined chiefly by environmental influences at the height of hypoxia (H = 0.15). Diastolic pressure was also found to be considerably dependent on environmental factors in the presence of acute hypoxia (H = 0.33).

With hypercapnia, the hemodynamic reactions were characterized by considerable interpair differences; however, no pattern whatsoever was demonstrable for the mean data (Figure 2b). According to M. Ye. Marshak [12], this could be attributed to the fact that with hypercapnia there is significant redistribution of regional blood flow, which has virtually no effect on either arterial pressure or minute volume. In MT, intrapair differences with moderate hypercapnia did not differ appreciably from those in DT; for all of the parameters studied, the

genetic coefficient was low. However, with 6% CO_2 in inhaled air, there were reliable intrapair differences in variability in MT and DT: H constituted 0.90 for minute volume, 0.80 for heart rate and 0.67 for systolic pressure. As in the case of hypoxia, stroke volume and diastolic pressure depended mainly on environmental factors (see Figure 2).

We were impressed by the fact that, at rest, the heart rate was characterized by great variability; however, with hypoxia and hypercapnia, as is the case with considerable physical exercise (pedaling on bicycle ergometer at up to 1000 kg-m/min), the magnitude of this parameter becomes genetically determined. A similar pattern was observed by other authors [13, 14 and others]. At the same time, the changes in stroke volume, which depends more on genotype at rest and is closely related to dimensions of the heart [15], were subject to the influence of random factors in the presence of loads.

Thus, emergency adaptation of man to acute hypoxia and hypercapnia depends on many elements determined by both genetic and environmental factors. This applies, first of all, to sensitivity of the respiratory center to hypoxia. Many authors have noted that the threshold level of reflex stimulation of the respiratory center is not the same in different people, and they related this difference to the functional state of the respiratory center and differences in individual adaptation to hypoxia [16]. Many works reported a significant decrease in sensitivity of peripheral chemoreceptor systems to hypoxia among high-altitude aborigenes [17-19]. At the same time, the ventilatory reaction to hypercapnia during adaptation to high altitudes does not change quantitatively, although regulation of respiration occurs at lower threshold $paCO_2$ levels [20].

A survey of the genetic distinctions of populations inhabiting high altitudes was not indicative of specific genetic adaptation of man to such altitudes. In the opinion of many researchers, the process of adaptation to high altitude is formed in the course of individual development and is in the nature of acclimatization rather than genetic determination [21-23]. Yet the opposite view is also held: mountain aborigenes are genetically adapted to their environment and this explains their greater functional capacities [24, 25]. At the present time, it is not deemed possible to offer an unequivocal answer to the question of extent to which the decline in sensitivity of the respiratory center of indigenous inhabitants of mountain regions is related to inborn, genetically fixed distinctions. Our data, which were obtained from a study of twins, indicate that the share of genetic factors in interindividual differences in sensitivity to hypoxia is quite significant; however, it is much smaller than the share of such factors that determine constitutional sensitivity to hypercapnia. Interindividual variability of sensitivity to hypercapnia depends by 98% on genetic factors and only 2% is referable to environmental ones. This indicates, once more, that the hypercapnic stimulus plays a leading role in regulation of respiration. It should also be noted that the prevalence of genetic factors in cardiorespiratory reactions to progressive hypoxia and hypercapnia is observed only with large loads, whereas such prevalence is not demonstrable with low levels of such stimuli.

The submitted data indicate that the process of emergency adaptation to acute hypoxia is determined by both genetically determined reactions and regulatory distinctions acquired in the course of ontogenesis. Hence, one can

alter, to some extent, sensitivity to hypoxia and the speed of triggering emergency adaptation mechanisms by means of conditioning; however, the range of such changes will depend on the individual's genotype. There is very probably insignificant possibility of altering sensitivity to hypercapnia, which is a stable individual constant that is genetically firmly determined.

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DETERMINATION OF PSYCHOPHYSIOLOGICAL CRITERION FOR PREDICTING EFFECTIVENESS OF THE ADAPTATION PROCESS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 6, Nov-Dec 82 (manuscript received 9 Nov 81) pp 58-62

[Article by V. P. Leutin and Ye. I. Nikolayeva]

[English abstract from source] This paper presents a criterion for measuring the efficiency of adaptation to an altered environment. The criterion is related to the quantitative evaluation of memory adequacy at early stages of the exposure to a new environment. An improvement in the reproduction of emotional words and a slight deterioration of the recollection of neutral words may be regarded as a prognostically significant criterion of the adaptation success. The lack of an improvement in the reproduction of emotionally important information and a significant deterioration of the recollection of neutral information at the early stages of adaptation is an adverse sign predicting a potential failure of the adaptation process.

[Text] It is very improtant to predict the state of human health both when an individual moves to new climate and geographic zones and during long-term spaceflights or chronic flight loads. There are data to the effect that the requirements made of a pilot of modern aircraft exceed his psychophysiological reserves [1] and more than 50% of the aircraft accidents occur because of the "human factor" [2]. It is also known that borderline states are the most common disease of the central nervous system in flight personnel, and in many cases they serve as grounds for disqualifying pilots [3-5].

Many authors who have studied the process of man's adaptation to Antarctica [6], the Extreme North [7] and area of construction of the Baykal-Amur Railroad [8] have noted that there is an increase in probability of neurosis.

It can be considered that a quantitative change in physiological parameters at the early stages of adaptation, which ultimately determine the change in functional state, would be a prognostically valuable criterion of success of the adaptation process.

Proper function of memory mechanisms is one of the main prerequisites for the body's adequate reactions to exogenous factors. Evidently, evaluation of

effectiveness of mnestic function at each phase of the adaptation process could emerge in the role of prognostic criterion, which would permit evaluation of the course of the adaptation process at its early stages.

Methods

A multiparametric analysis was made of the functional state of the human brain under subextreme (monsoon climate, 4-h time shift, South Kurilsk, 1976 expedition; moderately high altitude, 2600 m above sea level, Altay, 1977) and extreme conditions (high altitude, 3600 m, Pamirs, 1978).

We examined eight individuals from each expedition. They were examined on the 2d, 3d, 4th, 11th and 21st days of adaptation in South Kurilsk and Altay, on the 3d, 4th, 5th, 11th and 21st days in Pamir. Background studies were conducted three times in Novosibirsk (June).

Each subject was examined once during a scheduled day of the investigation, and recording was continued for 1 h. Test time was the same for each individual, in both Novosibirsk and the new locations. Examination of the group as a whole started at 0900 hours and ended at 1800 hours local time.

During the first part of the test, a tape recorder was used to run 6 lists of 20 words unrelated in meaning or sound, which were delivered at the rate of 1 word per second; there was a 4-min interval between readings of lists. Right after delivery of a successive list, the subjects tried to recall verbally the words they heard in any order. We prepared 8 sets of 6 lists for 8 subjects, so that on each day scheduled for testing all sets of lists were used; however, different lists of words were presented to each subject in each successive test. Thus, the lists of words were always analogous for the group as a whole and they were never repeated for an individual.

The words on the lists included 12 emotionally meaningful words chosen by means of independent expert evaluation and distributed over the lists with equal probability. In the course of the test, we recorded the electroencephalogram (EEG), electrocardiogram (EKG), galvanic skin responses (GSR) and phonogram (PG).

In the second part of the test, the subjects were asked to tap lightly with their right index finger on a vibration pick-up ["seismic" pick-up] at an arbitrary rate (seismoactogram--SAG), with 20-min recording of electrographic parameters (for detailed analysis of functional changes in the central nervous system).

The criterion for predicting effectiveness of the adaptation process was found by means of quantitative evaluation of recall of emotional and neutral words at the early stages of adaptation to extreme conditions (Pamirs). Recall of neutral words on the 11th day of adaptation served as grounds for separating the subjects exposed to these conditions into 2 subgroups. Reliability of differences from background data obtained in Novosibirsk was determined by the paired sign criterion [9].

Mountain climbers (11 people) constituted a special group; they were tested 3 times in Novosibirsk from 0900 to 2100 hours, then at the same times on the 2d and 3d days at the base camp (Pamirs) after ascents. For them, the number

of word lists was increased to 11. The first, training ascent was made to an altitude of 4200 m in 2 days and the second, to 5200 m, in 14 days. The last ascent was the first time they had traveled over a difficult route and required considerable nervous and physical strain of the climbers. On the basis of quantitative analysis of recall of emotional and neutral words after the first ascent, an effort was made to predict possible disturbances in the adaptation process of climbers during the second ascent.

Results and Discussion

On the 3d day of adaptation to subextreme conditions (South Kurilsk, Altay), there was poorer recall of neutral words and considerable improvement in recall of emotional words. At later stages (11th-21st days), there was better recall of neutral words and normalization of recall of emotional ones (see Table). At this stage, there were activation changes in the central nervous system, characterized by concurrent increase in frequency of dominant rhythm on the EEG, degree of activation reaction on the EEG when listening to and recalling words, build-up of spontaneous GSR and frequency of tapping on the pick-up.

Recall of emotional and neutral words (% of total number on lists) during various types of adaptation

TIME OF TESTS	EXPEDITION: SOUTH KURILSK 1976		EXPEDITION: ALTAY 1977	
BACKGROUND (NOVOSIBIRSK)	53.3	(36.7)	48.3	(41.1)
DAY OF ADAPTATION:				
2	45.0	(36.0)	40.0	(43.5)
3	6[illegible].5**	(31.3)*	65.8**	([illegible])*
4	49.2	(36.4)	43.3	(41.8)
11	55.0	(41.7)**	45.8	(46.7)*
21	50.0	(42.6)**	41.6	(43.8)

Notes:

1) Here and in Figure 1, background data are given according to results of third recording.
2) Percentage of recalled neutral words is shown in parentheses, recalled emotional words without parentheses.
One asterisk indicates $P<0.05$ and two asterisks $P<0.01$, as compared to background tests.

At the early stages of the adaptation process, differential formation of traces in memory of neutral and emotional words apparently reflects activation of the mechanism of selection of emotionally significant information. Improved recall of neutral words at the later stages is indicative of activation of memory processes, which could be instrumental in forming a new functional stereotype and stable reproduction thereof.

It can be assumed that activation of selection of emotionally meaningful information at the early stages of adaptation is a mandatory prerequisite for successful subsequent course of the adaptation process. Absence of activation of such selection at the early stages of formation of a new functional stereotype should apparently make it impossible to improve recall of neutral information at later stages of adaptation to extreme conditions. To check this hypothesis, under the extreme conditions (Pamirs) the subjects were divided into 2 subgroups according to efficiency of recall of neutral words on the 11th day of adaptation. The first subgroup consisted of subjects who presented improved recall of neutral words, as compared to base data. Their recall of emotionally meaningful words improved appreciably, with some decrease

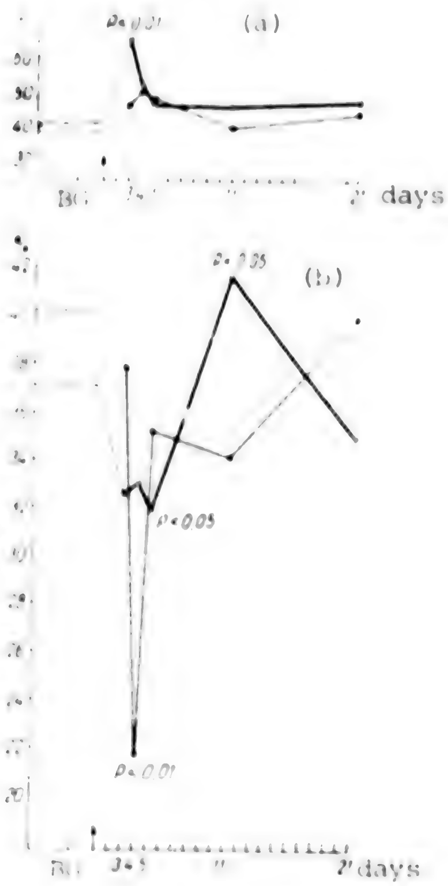

Figure 1.
Recall of neutral words at late stages of adaptation as a function of effectiveness of formation of memory trace of emotional and neutral words at early stages of exposure to new conditions.
Boldface and thin lines--word recall by 1st and 2d subgroups, respectively. X-axis, days at altitude of 3600 m, Pamirs.

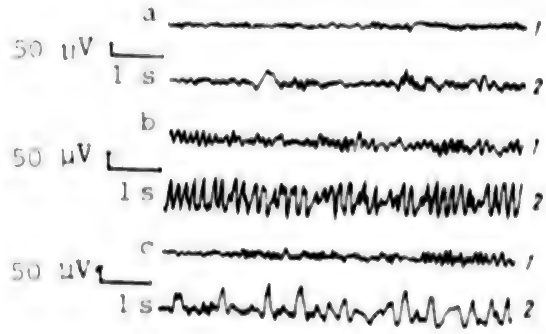

Figure 2.
Samples of original EEG tracings of 3 mountain climbers
Here and in Figure 3:
1) background
2) Pamirs after second ascent

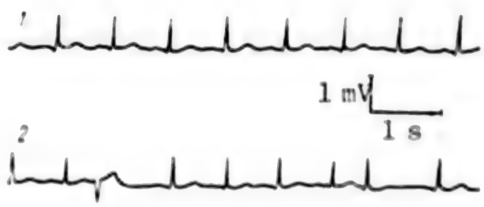

Figure 3.
Samples of original EKG tracings of one of the mountain climbers

in recall of neutral words at the early stages of adaptation (Figure 1, boldface line). The subjects in the second subgroup showed no improvement of recall of neutral words on the 11th day of adaptation. They remembered neutral words much worse (almost half), showing no change in level of recall of emotional words on the first days under new conditions (see Figure 1, thin line). EEG, EKG and GSR parameters differed more from background levels than in the subjects of the first subgroup. Thus, there was confirmation of the fact that activation of selection of emotionally meaningful words at the early stages of the adaptation process predetermines improvement of memory at later stages.

The prognostic significance of this criterion was checked in a study of mountain climbers using the method of exploratory forecasting: after the first ascent the subjects were divided into two groups according to presence or absence of activation of selection of emotional words (1st and 2d subgroups, respectively). After the second ascent (significant physical load and nervous tension) to an altitude of 5200 m for 14 days, the 1st subgroup of climbers (4 people) showed

no electrographic signs of pathology, in the 2d subgroup (7 people), the EEG presented waves in the θ and δ range (7 people) in a waking state (Figure 2), and sharpening of α waves (1 person). The EKG showed extrasystole (4 people, Figure 3), arrhythmia (3 people) and, occasionally, severe bradycardia (1). We were impressed by the fact that some of the subjects in this subgroup presented poorer recall of emotional words and worsening was more marked than worsening of recall of neutral words. Such a change in reaction to words that are emotionally meaningful to an individual is indicative of distortion of standards for evaluating the significance of incoming information.

Thus, improved recall of emotionally meaningful words with some worsening of recall of neutral words can be interpreted as a prognostically significant criterion of success of adaptation. Absence of improved recall of emotional information with significant worsening of recall of neutral information at the early stages is a sign that enables one to predict the possibility of impairment of the adaptation process.

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SEASONAL DYNAMICS OF CIRCADIAN RHYTHM OF HEMODYNAMICS AND ARTERIAL PRESSURE PARAMETERS IN PERMANENT RESIDENTS OF FOOTHILL AND HIGH-ALTITUDE REGIONS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 6, Nov-Dec 82 (manuscript received 10 Nov 81) pp 62-66

[Article by M. T. Turkmenov and T. K. Abdyldabekov]

[English abstract from source] Diurnal and seasonal variations of hemodynamics parameters and blood pressure in high altitude residents (3200 m above sea level) were studied. The physiological functions showed a distinct rhythmicity. Amplitude-phase characteristics of the physiological parameters were calculated according to the Kosinor program.

[Text] It has now been established that parameters of many physiological functions change consistently in the course of a day. The cardiovascular system (CVS) is one of the first to be involved in adaptive reactions, and it plays an important part in maintaining homeostasis under different climate and geographic conditions.

There have been numerous descriptions of the 24-h rhythm of heart rate (HR), blood pressure (BP) and minute blood volume (MV) [1-7]. Much material has been accumulated on seasonal fluctuations of these functional parameters in lowland residents. However, the results were found to be contradictory. For example, in the Baykal region [8] and arid zone [9], acceleration of HR and BP drop were noted in the summer, as compared to fall and spring. According to L. G. Filatova et al. [11], among residents of Crimea, an increase in mean daily level and amplitude of HR fluctuations is more marked, on the contrary, in winter than in summer. According to the data of the same authors, no appreciable differences in HR in different seasons were demonstrable in Kirghizia.

With regard to BP, seasonal and regional distinctions of circadian dynamics have been noted. According to several authors [10-12], there is elevation of BP in the winter and decline in the spring and summer. Many authors have reported a tendency toward rise of BP in the winter in southern regions, regions with a monsoon climate and in the Extreme North [13-17].

Our objective here was to investigate the seasonal dynamics of circadian rhythms of CVS parameters in permanent residents of foothill (760 m above sea level) and high-altitude (3200 m above sea level) regions.

Methods

We examined 40 men, 20 of whom live in the foothills and 20 at high altitude. These were essentially healthy laborers 21 to 26 years of age. We recorded physiological parameters every 4 h in the course of the day (at 1100, 1500, 1900, 2300, 0300 and 0700 hours local time): at night under basal metabolic conditions, in the daytime in the course of their usual work after a 30-45-min rest, in supine position. The temperature was kept at 18-22°C in the room where the tests were made. The data were submitted to mathematical processing on the Kosinor program using a YeS-1020 computer [18].

The material was submitted to analysis of spectral power to determine the frequency ensemble in the structure of circadian rhythm.

We used the following as criteria for evaluating adaptive function of the body with regard to the circulatory system: HR, systemic blood volume (SBV) and minute volume [MV] (according to Starr), cardiac index (CI), blood flow equivalent (BFE), BP_{min}, BP_{max}, dynamic mean (DM) BP (according to Korotkov) and peripheral resistance (PR, according to Poiseuille). We took into consideration the Kerde vegetative [autonomic] index (KVI) as an indicator of changes in tonic activity of the sympathetic and parasympathetic branches of the autonomic nervous system.

Results and Discussion

The results of examining circulatory parameters (Table 1) revealed that, at relative rest and state of basal metabolism, the young male subjects living in the mountains were characterized by reliably faster HR, high levels of MV, CI, SBV and BFE. Their BP levels were lower than in foothill residents Mean daily pulsed BP (BP_p) was the same.

Table 1. Annual mean-diurenal parameters of hemodynamics and BP in permanent residents of foothills and mountains under basal metabolism conditions at rest

PARAMETER	FOOTHILLS		HIGHLANDS	
	NOMINAL	ACTUAL	NOMINAL	ACTUAL
HR/MIN	—	65,7±0,2	—	67,2±0,3
MV, ML	3718±19	3996±27	3830±21	4187±22
SBV, ML	59,3±0,8	60,6±0,3	57,5±0,4	62,4±0,2
CI, ML/M^2	2211±84	2315±51	2192±76	2603±15
BFE, ML	1663±96	1501±19	1675±89	1726±20
KVI, ARB. UNITS		−14,0±0,8	—	−10,5±0,8
BP_{MAX}, MM HG	110,5±0,7	114,9±0,5	110,0±0,2	113,4±0,4
DM BP, MM HG	83,9±0,5	87,9±0,5	83,7±0,2	86,0±0,3
BP_{MIN}, MM HG	70,8±0,5	74,4±0,5	70,6±0,2	72,5±0,3
BP_P, MM HG	39,2±0,1	40,5±0,2	39,4±0,1	40,9±0,2
PR, $DYNE/S/CM^5$	1801±18	1876±24	1810±24	1702±12

Mean diurnal parameter of total PR was reliably higher in foothill residents, while KVI was indicative of a great shift of autonomic equilibrium in the parasympathetic direction, as compared to inhabitants of higher altitudes.

Mathematical approximation of the obtained MV, CI and KVI parameters (Figure 1) demonstrated a sinusoidal pattern of the circadian chronogram, apparently due mainly to HR. An analogous shape of curve for circadian rhythm was demonstrable for BP and total PR, but we should mention the counterphase structure of circadian PR rhythm. As indicated by the results of mathematical analysis, circadian rhythms of SBV and BFE were statistically insignificant.

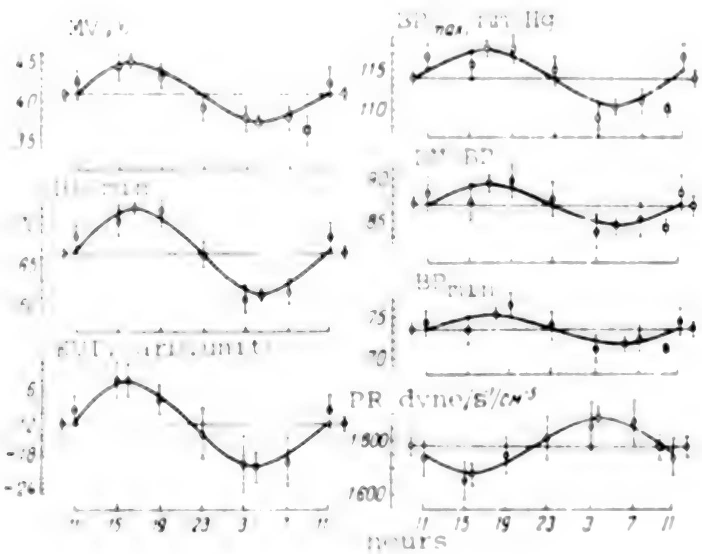

Figure 1.
Mean annual circadian rhythms of HR, MV, KVI and PR in permanent inhabitants of Kirghizia

The acrophase peaks of hemodynamic parameters were recorded at 1600-1700 hours and minimums at 0400-0500 hours. Hemodynamic and BP parameters of residents of Kirghizia corresponded to nominal standard levels at 0300-0700 hours. At other times, the numerical values of these parameters were above nominal levels (shown with cross on the right in Figure 1), particularly in the region of the acrophase maximum, 1500-1900 hours, whereas PR did not reach these levels. All this is inherent to virtually the same extent in permanent residents of both foothills and highlands (Figure 2).

Analysis of the structure of diurnal chronograms of circulatory parameters of healthy people living permanently in mountainous regions revealed that homeostatic and homeokinetic CVS reactions are involved in adaptation to daily changes in the environment. At night, when the influence of exogenous factors is drastically diminished, minimum strain of regulatory mechanisms is required. Hemodynamic parameters and BP at these times conform to nominal levels (see Figures 1 and 2). And, apparently, regulation of the circulatory system is effected only by the peripheral autonomic mechanism, for which reason it is possible to restore the energy resources of the vasomotor center. This is indicated by the increase in propulsive activity, contractility and low tonic tension of the heart with corresponding decrease in expenditure of energy and marked shift of autonomic equilibrium in the parasympathetic direction.

The change from rest (night time) to active state (daytime hours) is associated with intensification of activity of the hypothalamo-hypophysio-adrenal system, which is directed toward maintaining efficiency exchange of gases, delivery of blood and increased blood oxygenation. The actual mean daily and maximum values of hemodynamic and BP parameters exceed the nominal levels, while PR does not reach it (Figures 1 and 2).

Maximum hemodynamic parameters near the acrophase exceeded the minimum by 20-24%.

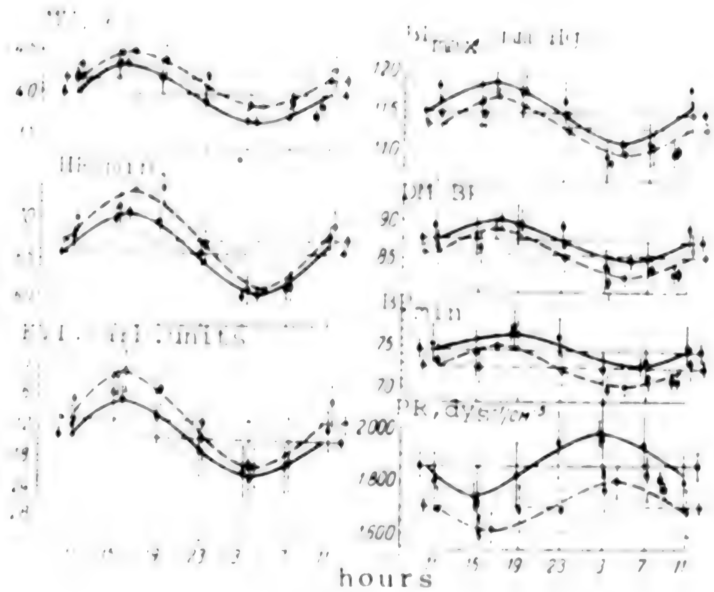

Figure 2.
Mean annual circadian rhythms of HR, MV, KVI and PR in permanent residents of foothills (solid lines) and highlands (dash lines)

Physical and nervous-emotional loads sometimes elicit changes in the structure of the circadian chronogram of circulatory parameters, which are manifested in the form of physiological desynchronosis, consisting of change in amplitude, shift of mean diurnal level, shift of acrophases, drop of physiological level, etc. A state of physiological desynchronosis is particularly well demonstrable when we analyze seasonal dynamics of circadian rhythms of circulatory parameters, which is indicative of difference in intensity of CVS function in adapting to seasonal changes in environmental conditions. This phenomenon (seasonal physiological desynchronosis) confirms the opinion of some authors [19, 20] that desynchronosis phenomena are observed in circadian organization of healthy man and that adaptation to migration of time sensors is effected by the acquired capacity to shift acrophases of all the body's psychophysiological functions within a certain range (within the range of a certain zone of migration of acrophases). According to our data, this zone of migration of acrophases of hemodynamic parameters and BP on the 24-h time scale constitutes almost 8 h in the course of the year, while the seasonal shifts constitute 2-3 h. This very probably indicates that there is a wide band in this zone of synchronization of interaction between regulatory mechanisms of the circulatory system.

At the same time, it should be noted that the sinusoidal shape of diurnal curves with a 24-h period of physiological parameters in different seasons does not undergo appreciable changes (Table 2). This is indicative of lability of adjustment of the circulatory system in the course of the year in a state of relative rest.

According to maximum daily mean and minimum MV levels, some intensification of activity of regulatory mechanisms is observed in foothill residents in the spring and summer and a decrease in the fall and winter months. Relative stability of regulatory activity is inherent in highland residents. With respect to nominal MV, an identical pattern of coordinated change with season without appreciable differences is demonstrable. Its level corresponds to the minimal value of actual parameters characterizing optimum function of the circulatory system under basal metabolic conditions. We observed only a reliable decline of minimum MV level in foothill residents in the fall and winter, which is apparently indicative of an increase in physiological reserve for this parameter.

[illegible] Seasonal [illegible] of circadian rhythm of MV and BP in permanent residents of foothills (FH) and highlands (HL)

SEASON	SITE	TIME OF DAY, HOURS					
		[illegible]	[illegible]	19	23	3.00	7.00
MV							
SPRING	FH	4352 ± [illegible]	4853 ± 101	4197 ± 134	4021 ± 147	4067 ± 100	3866 ± 94
	HL	4156 ± 206	4418 ± 142	4386 ± 120	4011 ± 128	3911 ± 128	4035 ± 161
SUMMER	FH	4329 ± 20[illegible]	4835 ± 265	4748 ± 208	4389 ± 199	3792 ± 154	3858 ± 147
	HL	4391 ± 153	4527 ± 142	4391 ± 212	4211 ± 153	9852 ± 173	3749 ± 139
FALL	FH	3911 ± 124	4288 ± 156	4052 ± 146	3893 ± 125	3410 ± [illegible]2	3535 ± 10[illegible]
	HL	4319 ± 1[illegible]3	4512 ± 178	4485 ± 192	4170 ± 197	3889 ± [illegible]72	3746 ± [illegible]65
WINTER	FH	4005 ± [illegible]81	3980 ± 208	3761 ± 179	3350 ± 152	3356 ± 180	3516 ± 146
	HL	4338 ± 138	4284 ± 173	4358 ± 166	4385 ± 154	3857 ± 145	3904 ± 121
BP							
SPRING	FH	116,0 ± 1,9	110,2 ± 2,2	113,6 ± 2,2	114,5 ± 2,6	106,4 ± 1,9	107,6 ± 1,9
	HL	111,4 ± 1,7	113,0 ± 1,9	113,4 ± 1,3	112,3 ± 1,6	107,7 ± 1,7	110,7 ± 1,5
SUMMER	FH	112,6 ± 2,2	110,3 ± 2,7	111,3 ± 2,6	111,5 ± 2,6	106,2 ± 2,1	108,9 ± 2,5
	HL	114,0 ± 2,3	114,8 ± 2,4	118,8 ± 2,3	114,3 ± 2,3	111,0 ± 1,9	111,9 ± 1,9
FALL	FH	115,4 ± 1,[illegible]	1[illegible]7,2 ± 2,5	116,4 ± 2,3	115,0 ± 4,5	106,8 ± 2,3	107,0 ± 2,5
	HL	120,0 ± 1,8	118,4 ± 2,2	121,4 ± 2,3	118,1 ± 2,0	111,2 ± 1,9	115,8 ± 2,3
WINTER	FH	128,[illegible] ± 2,[illegible]	12[illegible],9 ± 3,5	128,6 ± 3,2	125,3 ± 2,9	120,4 ± 2,8	122,4 ± 3,0
	HL	115,0 ± 2,[illegible]	11[illegible] ± 1,8	115,6 ± 2,1	109,3 ± 2,3	106,8 ± 2,5	107,2 ± 2,1

Conversely, with regard to systolic BP, maximum activity of the vasomotor center in foothill residents was observed in the winter, the minimum being referable to summer and fall. Accordingly, the actual systolic BP in the winter was higher than the nominal level, whereas in the summer and fall it did not reach it. In highland residents, there was some increase in tonus of the vasomotor center according to systolic BP level in the fall and it was minimal in the winter and spring. Accordingly, actual systolic BP did not reach the nominal level in the winter, whereas in other seasons the nominal values of these parameters corresponded to the minimum levels.

Analogous changes in intensity of external respiration and CVS functions, in their diurnal dynamics have been demonstrated in individuals working in shifts.

Thus, it should be noted that the subjects examined present highly flexible CVS function. This is equally inherent in the micropopulation groups of both foothills and highlands. Consequently, acclimatization of high-altitude regions does not have an appreciable effect on the different parameters in the structure of circadian rhythms of circulation. Only amplitude, levels and acrophases, as well as the frequency component of the circadian rhythm of circulatory parameters and blood pressure change in different seasons, i.e., marked physiological desynchronosis is demonstrable.

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STUDY OF EFFECT OF WEIGHTLESSNESS ON THE AQUATIC FERN, AZOLLA

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 6, Nov-Dec 82 (manuscript received 10 Jul 81) pp 66-68

[Article by Ye. Ya. Shepelev, Nguyen Hyu Thyoc, V. A. Kordyum, G. I. Meleshko, T. B. Galkina and V. G. Man'ko (USSR and Socialist Republic of Vietnam)]

[English abstract from source] An exposure to 6-day weightlessness of the fern Azolla pinna R. Br. symbiotically related to the nitrogen fixing alga Anabena azollae did not affect the main biological characteristics (growth, development and morphological structure) of both fern plants and algae. The exposure did not influence the growth rate or subsequent Azolla generations on the Earth.

[Text] In this report we submit the results of a study of the effect of weightlessness on some biological characteristics of a representative of higher plants, the Azolla aquatic fern (Azolla pinata). The microscopic blue-green alga (Anabena azolla) grows and reproduces with this plant, in its air chambers, and it is capable of assimilating atmospheric nitrogen and converting it into nitrogen-containing compounds suitable for plant nutrition. The rate of nitrogen fixation for this symbiosis is exceptionally high, and it exceeds the rate for other nitrogen-fixing organisms. For this reason, Azolla that reproduces in rice paddies improves soil fertility and results in a saving of nitrogen fertilizers.

This plant is a convenient model for the study of the biological role of gravity. Being a higher plant, Azolla is among the smallest ones and reproduces very rapidly, so that a change of generations can be obtained within a short time. It inhabits the surface of water, which is valuable to studies in weightlessness, since it provides for uniform water conditions for experimental and control plants. An equally interesting property is symbiosis with algae, which permits investigation of ecological relations between Azolla and its nitrogen-fixing companion. Moreover, Azolla is of interest to closed ecological systems by virtue of its high degree of nitrogen fixation and rapid growth. Azolla's property of fixing atmospheric nitrogen in biological life-support systems (BLSS) for man makes it possible to compensate for processes of "uncoupling" of nitorgen, which occur in biological and physicochemical mineralization of organic waste in the system. Concurrently, active photosynthesis can be used for air regeneration.

Thus, the tested system is of interest not only to the study of the general biological question of effects of gravity on higher plants, but from the standpoint of its use in human BLSS.

Methods

This study was conducted in an IFS-2 instrument, which is a sealed plexiglas chamber 105×90×60 mm in size, with hydrophilic coating on the inside surface. We placed nutrient medium and the tested plants into the chamber; they were placed on a textile substrate to stabilize their spatial position. We used 2 instruments in this study, with 9 plants (thalli) in each. The instruments were inserted in orbit in the dark, then placed in the "lounge" [?] of the Salyut-6 station near a light. Illumination on the surface of the instrument constituted 3-4 klux and temperature was 22-23°C. Concurrently with the flight experiments (FE), control ones were conducted after 2 days: laboratory control (LC) and transport control (TC). The duration of each was 6 days.

In the first analysis of flight material, we examined the condition of thalli (number of segments per thallus and leaflets per segment; number of dead segments, presence of rhizoids), chlorophyll content of fern and algal cells (scaled to 1 leaflet), qualitative composition of concomitant microflora (according to nature of colonies).

Results and Discussion

Analysis of our results revealed that the leaf surface of plants was the same in the FE and TC, and it underwent virtually no change, as compared to the findings at the start of the study. Absence of noticeable biomass increment was apparently related to equivalent loss for respiration, which is attributable to the low level of photosynthesis due to loss of rhizoids. In the LC, the number of plants almost doubled within the period of the study (Table 1).

Table 1. Condition of Azolla plants subjected to weightlessness, as compared to ground-based control (number of structural elements)

Experimental conditions	At start of study			At end of study		
	thallus	segments/ thallus	segments	thallus	segments/ thallus	segments
FE	9	12-16	None	5	3-4	115
TC	9	12-16	"	1	3-4	130
LC	9	12-16	"	17	12-16	None

The difference between growth rate under different conditions (including the difference between TC and LC) can be attributed to adverse changes in the condition of the plants. In the FE and TC, most fern thalli separated into segments (see Table 1) and lost their rhizoids. Such morphological changes in the plants led, in turn, to a decline in growth rate, which is often observed under laboratory conditions. Since morphological changes in fern thalli occurred not only in the FE, but TC, it can be assumed that they are not due to the biological effect of weightlessness, but impaired orientation of plants and mechanical factors during transportation to the site of the experiment.

Table 2. Some characteristics of Azolla submitted to weightlessness, proportion of algae and fern (end of the experiment)

Experimental conditions	Medium pH	Chlorophyll, %	Algal cells/leaflet
FE	7.1	0.40	$14 \cdot 10^3$
TC	7.1	0.35	$10 \cdot 10^3$
LC	6.0	0.30	$10 \cdot 10^3$

The pH of the medium, in which the fern was grown, was higher in the FE and TC than the LC, which is also indicative of poorer fern growth in the FE and TC. In the case of active Azolla growth, there is an acid shift of pH.

The amount of chlorophyll (for algae and fern together) was virtually the same in all experiments, which is indicative of retention of normal level of plant vital functions.

The blue-green alga, Anabena, which developed together with the fern, did not undergo any changes in the FE. Algae were collected into long filaments; they presented intensive coloration and morphologically did not differ from the control. Differences between parameters in the FE, LC and TC were demonstrable only with regard to impaired proportion of fern to algae (Table 2): there was a tendency toward increase in relative number of algae per fern thallus in the FE.

There were some differences in number and composition of concomitant bacteria. In the FE, there were many bacteria, with a shift in the direction of those forming white colonies. We are continuing to identify the different groups of bacteria.

Thus, analysis of living biological material of the aquatic fern, Azolla, failed to demonstrate an appreciable difference in the plant features studied between parameters in the FE and TC. This warrants the conclusion that the observed disturbances in condition of fern thalli and rhizoids are related to impaired orientation of plants and mechanical factors, to which they were exposed during transportation of the instruments.

Subsequent cultivation of Azolla plants submitted to weightlessness revealed that all of the disturbances were reversible. Under laboratory conditions, the plants grew and multiplied normally. Restoration of rhizoids started on the 2d experimental day. According to increment of dry matter, carbon dioxide uptake and oxygen output, the growth rate of Azolla in the FE did not differ from the LC and TC. The assimilation index ($CO_2:O_2$ ratio) constituted about 1, which was close to the values obtained in the control variants. Consequently, exposure of plants to weightlessness for 6 days did not affect growth rate or photosynthesis in subsequent generations of Azolla and unicellular Anabena algae.

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NATURAL IMMUNITY FACTORS AS INDICATORS OF REACTIONS TO HELIOGEOPHYSICAL FACTORS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 6, Nov-Dec 82 (manuscript received 28 Dec 81) pp 68-71

[Article by L. A. Gushchina]

[English abstract from source] The data treatment of immunological examinations of 2300 donors with the aid of the Distribution and Factor Analysis programs revealed a distinct relationship between natural immunity parameters and the heliophysical activity. The main heliophysical complex included solar flare intensity, radiofrequency radiation and surface area of sunspots. Among the natural immunity parameters humoral factors of nonspecific protection showed the greatest variations.

[Text] It is important to investigate mechanisms of assuring reliability of the organism exposed to the negative effects of environmental factors in order to comprehend the physiological bases of vital functions [1, 2]. Among these mechanisms, factors of natural immunity occupy a definite place [3-5], although their role in body reactions to constantly changing environmental conditions has been little-studied as yet. The existing information pertains mainly to seasonal fluctuations of different parameters, among which nonspecific immunity factors hold the main place [6, 7]. Deeper investigation of this question would permit demonstration of the mechanisms of biotropic effects of exogenous factors and development of optimum methods of disease prevention [8-10]. Our objective here was to investigate the distinctions of natural immunity parameters as related to heliogeophysical parameters, and to assess the possibility of making practical use thereof as additional informative tests to characterize reactions to heliophysical factors.

Methods

We made an immunological study of 2300 donors at the blood transfusion center in Orenburg in the period of 1977-1978. We examined humoral factors of natural resistance (bactericidal activity of serum--BAS, lisozyme, complement, β-lysins), cellular element of nonspecific protection (phagocytic activity of neutrophils) in peripheral blood, as well as quantitative and functional parameters of the T system (E-ROK [complement deviation test?], blast transformation of lymphocytes with phytohemagglutinin) and B system of immunity (EAC-ROK, immunoglobulins, normal antibody titer). The heliogeophysical factors were represented by parameters of solar activity (quantity and area of

sunspots, intensity of solar flares, magnitude of radiation in the 2800 MHz range), which were determined during the period of the solar cycle (27 days), on the day of the immunological examination, as well as during the 3d and 7th days preceding this examination.

In addition, we analyzed 42,655 calls referable to cardiovascular crises (hypertensive, myocardial infarction) received by the emergency station of Orenburg, according to statistical charts for the same period of time (1977-1978).

The data were processed using a YeS -1020 computer using the "Distribution" and "Factor Analysis" programs, which enabled us to simulate processes of correlation between the phenomena studied together, using large samples.

Results and Discussion

Factor analysis revealed three statistically significant factors reflecting substantial links between parameters of natural immunity and solar activity.

Factor 1 constituted 51.6% of total variance. There were 18 immunological parameters involved in its formation and, consequently, in formation of the studied links. Humoral factors of nonspecific protein made the highest percentile contribution: β-lysins (40%), lysozyme (38%) and complement (31%). IgM, β-lysins, activity and intensity of phagocytosis, as well as spontaneous blast transformation of lymphocytes, made a positive contribution to formation of this factor, while the other parameters made a negative one. Parameters characterizing the most essential specific and nonspecific mechanisms of natural immunity had negative signs.

The most important distinction of parameters of solar activity was predominant involvement of values characterizing the 27-day solar cycle in formation of the first factor. The percentile contribution of different heliophysical parameters to formation of this factor constituted 56% for radiation, 44% for area of sunspots and 38% for intensity of solar flares. In addition, links between immunological parameters and characteristics of solar activity corresponding to the day blood samples were taken were also significant. The specific significance of different parameters of solar activity during this period constituted 31% for radiation, 18% for area of sunspots and 27% for intensity of solar flares.

The links between these parameters of solar activity in the periods 3 and 7 days before taking blood with natural immunity factors were substantially less significant.

As for factor 1, humoral mechanisms of natural resistance made the largest contribution to formation of factor 2, which constituted 27% of total variance: β-lysins (38%) and lysozyme (34%). The distribution of these parameters according to direction of links to solar activity was identical to that within factor 1.

The heliophysical complex isolated in factor 2 was represented by the same characteristics. However, unlike the first factor, we demonstrated here a more marked link between natural immunity factors and intensity of radiowave radiation during the 27-day solar cycles (30% contribution) and on the day blood was taken (15%).

As for factor 3 (19% of overall variance of factors), its distinction was that it reflected primarily the links between humoral mechanisms of nonspecific resistance and intensity of solar flares. At the same time, as was the case for the first two factors, heliophysical parameters corresponding to the 27-day solar cycle, as well as their values on the day blood samples were taken, were of deciding significance to formation of links with parameters of natural immunity.

Thus, our factor analysis is indicative of existence of marked links between heliophysical characteristics and natural immunity. There is distinct demonstration of the main heliogeophysical complex, which is represented by radiation in the radiowave range, area of sunspots and intensity of solar flares.

It is significant that expressly this complex also had a marked effect on the incidence of cardiovascular accidents (hypertensive crises and myocardial infarction). The results of the factor analysis enabled us to single out two main factors, which constituted 71.4% of overall variance. According to the characteristics of factor 1, there were high factor loads reflecting manifestation of cardiovascular pathology that were referable to the number of calls due to hypertension (29-36%) and myocardial infarction (21%). In turn, the heliophysical complex was represented by parameters characterizing the intensity of solar flares in 27 days (47% contribution to formation of the factor) and on the day of a call (26%), magnitude of radiowave radiation at these times (36 and 23%) and area of sunspots (31 and 18%).

An analogous link between number of calls to patients with cardiovascular diseases and heliogeophysical parameters was demonstrable in factor 2.

Thus, our results are indicative of high sensitivity of natural immunity parameters to heliophysical factors, and they indicate that it is theoretically possible to use them to assess the adverse effects of a set of environmental factors on man. At the same time, our comparative analysis of sensitivity of mechanisms of natural immunity to changes in heliophysical parameters enables us to unequivocally assess the higher informativeness of natural resistance factors, as compared to quantitative and functional characteristics of the immunogenetic system.

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EFFECT OF LONG-TERM EXPOSURE TO HIGH-INTENSITY STEADY MAGNETIC FIELD ON ACTIVITY OF ADRENERGIC AND CHOLINERGIC SYSTEMS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 6, Nov-Dec 82 (manuscript received 19 Nov 81) pp 71-74

[Article by L. D. Klimovskaya and A. F. Maslova]

[English abstract from source] The mice exposed for 1 month to a constant magnetic field of 1.6 T showed a significant increase in the epinephrine and norepinephrine concentration of blood. The acetylcholine content of blood grew on the 3d week of the exposure. The content of neurotransmitters in the brain tissue increased during the 3d week and returned to the normal by the end of the exposure.

[Text] We previously demonstrated that brief exposure to a steady [constant] magnetic field (SMF) of high intensity elicits a marked reaction by adrenergic and cholinergic systems. Exposure of rabbits to SMF with induction of 0.4 T for 1 h led to increase in blood epinephrine (E), norepinephrine (NE) and acetylcholine (AC) concentrations, as well as more intensive catecholamine (CA) production in the adrenals [1].

Our objective here was to investigate the dynamics of changes in levels of E, NE and AC in mouse blood and brain during month-long exposure to high-intensity SMF.

Methods

This study was conducted on 280 male F_1 mice. The magnetic field was created with an SP-57A electromagnet with 900-mm diameter of pole tips and gap of 100 mm. Magnetic induction of the field remained virtually unchanged over a radius of 380 mm, decreasing by 20% toward the edge of the pole tips. The magnetic field was strictly constant. The mice were placed in the electromagnetic gap for 30 days in plexiglas containers. They were exposed to SMF with induction of 1.6 T, the magnetic lines of force passing vertically. For the same period of time control mice were in an electromagnet phantom. Upkeep conditions were the same for both groups of mice, with good access of air, as well as free movement of animals. The electromagnet was turned off daily for 30 min. During this time, the containers were cleaned and the animals were fed. Tests were

made on the 1st, 4th, 7th, 10th, 15th and 30th days of exposure to the SMF, immediately after terminating exposure and on the 7th day of the recovery period. We sacrificed by decapitation 10 mice from the control and experimental groups at the same time. We assayed blood and brain E, NE and AC levels using polarographic analytical methods [2-4].

Results and Discussion

SMF with induction of 1.6 T elicited within 24 h an increase in blood E, NE and AC concentrations, as well as increase in brain neurotransmitters (see Table). As can be seen in Figure 1, the dynamics were the same for changes in concentration of blood E and NE in the course of 30-day exposure of animals to SMF. For the first 4 days, there was significant increase in blood CA content, followed by gradual decrease, constituting the control level only by the 23d day. On the 30th day there was another increase. Mouse blood CA content did not differ from control levels on the 7th day after exposure for 30-days to SMF. Thus, for virtually all 30 days in the SMF of high intensity, the blood concentrations of E and NE exceeded the control level significantly, which indicates that there was an increase in activity of hormonal and mediator elements of the adrenosympathetic system [5]. This was not associated with any appreciable change in proportion of catecholamines. We only found some elevation of NE, as compared to E level. The high ratio of neurogenic component to adrenomedullary one is a sign of high degree of excitability of the cortex and and hypothalamus [6].

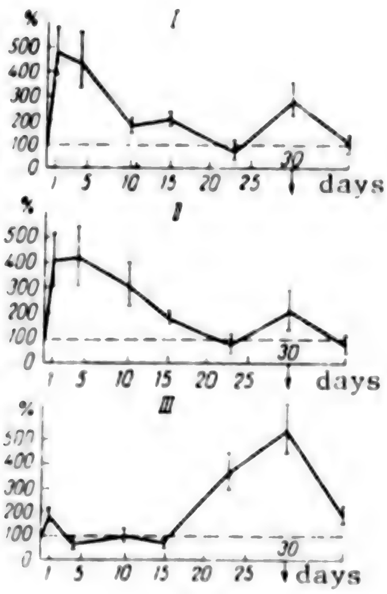

Figure 1.
Dynamics of changes in mouse blood norepinephrine (I), epinephrine (II) and acetylcholine (III) concentration during 30-day exposure to SMF with induction of 1.6 T

Here and in Figures 2 and 3: X-axis, day in SMF; y-axis, levels of indicated substances (% of control). Arrowhead shows end of exposure.

Blood AC concentration, which increased on the 1st day in the SMF, rapidly decreased and for the next 2 weeks fluctuated in the range of the control levels. In the 3d week, AC content increased drastically and held at high levels to the end of the period of exposure to SMF. Blood AC concentration remained somewhat increased even 7 days after the end of exposure (see Figure 1).

The balance between biologically active substances in blood was shifted in the direction of CA during the first half of the SMF exposure period and toward AC in the second half of this period. This is distinctly seen in Figure 2, which illustrates the dynamics of changes in proportion of CA and AC.

Effect of exposure to 1.6-T SMF for 24 h on amounts of neurotransmitters (in μg/ℓ) in mouse blood and brain

SUBSTANCE	BLOOD		BRAIN	
	CONTROL	EXPERIMENT	CONTROL	EXPERIMENT
EPINEPHRINE	8,56 ± 1,07	27,98 ± 4,70*	0,069 ± 0,015	0,223 ± 0,053*
NOREPINEPHRINE	8,69 ± 1,37	45,23 ± 13,28*	0,137 ± 0,030	0,429 ± 0,108*
ACETYLCHOLINE	1,46 ± 0,24	4,18 ± 0,74*	0,187 ± 0,05	0,493 ± 0,112*

* $P<0,05$.

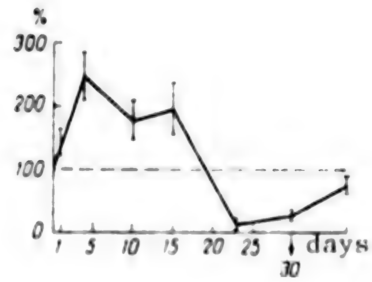

Figure 2.
Dynamics of changes in CA and AC proportion in blood during 30-day exposure to SMF with 1.6 T induction. X-axis, CA and AC proportions (% of control)

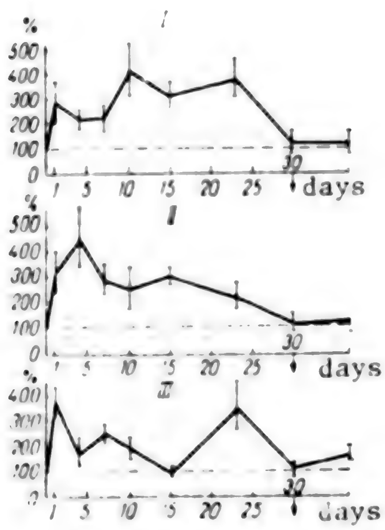

Figure 3.
Dynamics of changes in NE (I), E (II) and AC (III) in mouse brain tissue during 30-day exposure to 1.6-T SMF

The phasic nature of changes in humoral balance with prevalence of function of adrenergic mechanisms in the first phase and cholinergic mechanisms in the second phase is apparently a reflection of complex correlations between the adrenosympathetic and vago-insulin systems during long-term exposure to SMF. The development of a nonspecific protective reaction occurs with prevalence of the more reactive adrenosympathetic system which furnishes the emergency needs of the body. At the same time, maintenance of homeostasis is related to preservation of optimum balance between activity of ergotropic and trophotropic mechanisms, which makes it necessary for the parasympathetic system to participate in adaptive processes [7, 8]. From this point of view, synchronous and synergistic changes in catecholamine and acetylcholine content are more beneficial than reciprocal ones [9, 10]. Perhaps, the significant increase in blood AC in the second half of the period of exposure to SMF is the reuslt of an excessive reaction by compensatory mechanisms directed toward restoring equilibrium, which was impaired by prolonged activation of the adrenosympathetic system. Proceeding from this point of view, the increase in CA on the 30th day of exposure to SMF could be attributed to a compensatory reaction of the adrenosympathetic system, which retained its reserve capacities.

As can be seen in Figure 3, the high levels of NE and E persisted stably in brain tissue up to the 23d day of exposure to SMF. By the 30th day of mouse exposure to SMF there was normalization of brain CA content. AC content underwent somewhat greater fluctuations. However, like the CA content, it mainly exceeded the control level for the first 3 weeks and reverted to normal only by the 30th day.

Thus, in the course of prolonged exposure to SMF, we observed accumulation of neurotransmitters in brain tissue over a long period of time, and this applied equally to adrenergic and cholinergic systems. Evidently, there is activation of neurotransmitter systems during exposure to SMF, with prolonged persistence of a high level of compensatory processes which provide for a faster rate of resynthesis than rate of utilization of neurotransmitters. The question of causes of accumulation of E is somewhat different. The possibility that brain tissue synthesizes it is not entirely rejected; however, the increase in brain E content during exposure to extreme factors is attributed more often to its penetration from blood as a result of greater permeability of the blood-brain barrier [5, 11].

As we could see, there was intensification of activity of adrenergic and cholinergic mechanisms of the brain by the 30th day of animal exposure to SMF. By this time, there was normalization of neurotransmitter levels in the brain, which is apparently indicative of adaptation of central neurotransmitter systems to SMF. However, the presence at this time of marked humoral changes is indicative of incomplete adaptive alteration in body functions and retention of signs of strain on adaptation mechanisms.

It should be noted that we failed to demonstrate signs of functional depletion of adrenergic and cholinergic systems during exposure to SMF. The disturbances referable to humoral balance rapidly disappeared after the animals were removed from the SMF. All this indicates that, when the period of exposure to SMF of high intensity is long enough, a high level of adaptive and compensatory processes is retained. However, for definitive interpretation of the nature of the demonstrated changes, it is necessary to assess the state of regulatory mechanisms with use of functional tests [loads]. This would enable us to evaluate the functional state and adaptive capacities of an organism exposed to high-intensity SMF for a long time.

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DYNAMICS OF HOUSE FLY LARVA GROWTH ON SOME FORMS OF ORGANIC WASTE IN A BIOLOGICAL LIFE-SUPPORT SYSTEM

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 6, Nov-Dec 82 (manuscript received 15 Jan 82) pp 74-76

[Article by Ye. G. Golubeva and T. V. Yerofeyeva]

[English abstract from source] The time-course of the growth of Musca domestica larvae on organic wastes (human and Japanese quail excrements) was studied as a function of the egg density. An increase in the density of the substrate contamination reduced the weight of pupae and III instar larvae. The density effect in the case of quail excrements was seen earlier than in the case of human excrements. The larval weight on quail excrements was much lower than on human excrements, the density of substrate contamination being equal. On human excrements larvae grew more actively than on quail excrements--the magnitude of their relative increase was higher beginning with the 2d day of development. The density effect and the time-course of the larval growth on the substrates used show that human excrements are a better nutrient medium for fly larvae.

[Text] When studying the possibility of house fly larvae for utilization of organic waste in a biological life-support system (BLSS) for man, it is necessary to assess the biological adequacy of waste in this system as a source of nutrition for larvae.

The properties of the substrate, in which larvae develop, determine the distinctions of the fly's life cycle [1, 2]. The life cycle of Musca domestica L. starts with oviposition and ends with formation of pupae and hatching of flies from them. Morphogenesis occurs mainly at the pupa stage; the larvae is almost exclusively a stage of nutrition and growth. The size of the pupa, as well as viability of pre-imago stages, depend on the diet of the larva [1, 3]. In turn, the amount of eggs that could potentially be laid by the female is proportional to her size [4]. Thus, the quantity and properties of substrate in the larval stage have an appreciable influence on subsequent stages in the life cycle of the house fly.

Our objective here was to investigate the dynamics of house fly growth on different types of organic waste inherent in BLSS and the effect of egg density in the substrate on larval growth.

Methods

House fly eggs were placed in human excretions and Japanese quail droppings (which are a potential element of future human BLSS), at the rate of 0.25, 0.5 and 1.0 mg eggs/g substrate (moist mass). Cardboard containers, 500 cm^3 in size, with a polymer coating were used for larval development, and 100 g substrate was placed in each of them. Experiments were repeated 3 times for each egg density at air temperature of +25°C and relative humidity of 55-60%. During the period of development from egg to pupa, the larvae were weighed daily on a torsion balance, then a binocular used to identify the developmental stage on the basis of the posterior spiracles. We took 4-5 samples from each container, containing 10 to 20 larvae, for weighing. At different stages of larval growth, we calculated relative weight gain using the formula, $R = \Delta W/W_0$, where R is relative gain, ΔW is change in mass and W_0 is initial body mass [5].

Reliability of quantitative results was evaluated using Student's criterion for small samples, with significance level of $\alpha = 0.05$ [6].

Results and Discussion

It is known that diptera larvae undergo several stages of development (instars) separated by molts. For house fly larvae, a distinction is made between three larva stages and one pupa stage. The duration of each stage is different. In our experiments, development of larvae at the second instar lasted 2 days and at the third, 3 days. At the end of the third instar, the larva reaches maximum weight and ceases to take nourishment. Growth stops, the larva evacuates its intestine, selects a place for pupation and becomes immobile (prepupal phase). The transitions to the next stages of the life cycle after growth stops (prepupa and pupa) are associated with considerable weight loss.

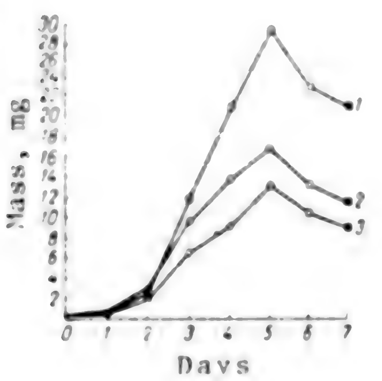

Figure 1.
Dynamics of larval weight during development in Japanese quail droppings, with different egg density in substrate.
Here and in Figure 2:
1-3) density of 0.25, 0.5 and 1.0 m/g, respectively

Dots, triangles and circles represent larvae in the first, second and third instars, respectively; white squares represent prepupae and black ones, pupae.

With the tested substrates, the density of egg placement had a markedly adverse effect on the weight of the third instar larvae and pupae (Figures 1 and 2). An adverse effect of population density has also been noted for animals referable to different systematic groups [5, 7, 8]. R. Chauvin [8] believes that in large insect populations the influence of density on growth is due to changes in their habitat under the effect of diverse discharges, including excrements, rather than competition for food alone. In the opinion of

other researchers, living space, rather than food, is the growth-limiting factor, i.e., the mechanical effect of individuals upon one another when density is high [5].

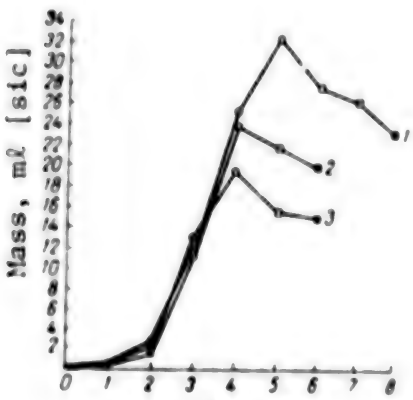

Figure 2.
Dynamics of larval weight during development in human excrements with different egg density in substrate

Relative weight gain (per day of development) in house fly larvae growing in human excrements and Japanese quail droppings

SUBSTRATE	DENSITY, MG/G	DAY OF DEVELOPMENT				
		1	2	3	4	5
HUMAN EXCREMENTS	0,25	2,8	8,2	4,9	0,5	—
	0,5	2,5	8,0	6,3	1,2	—
	1,0	2,8	8,1	2,4	1,2	—
JAPANESE QUAIL DROPPINGS	0,25	5,4	4,8	3,8	0,7	0,4
	0,5	5,9	4,7	2,7	0,5	0.4
	1,0	4,1	4,7	2,3	0,4	0,4

In quail droppings, the effect of density on larval growth begins at earlier stages of development than in human excrements (see Figures 1 and 2).

The effect of density on relative gain is not distinctly demonstrable; however, relative gain with a density of 1 mg/g is reliably lower than with a density of 0.25 mg/g on the 3d-4th day of development on quail droppings (see Table).

The weight of pupae is considerably lower in quail droppings than human excrements with the same egg density in the substrates (see Figures 1 and 2). It is known that insect weight depends on feeding conditions [7]. In this case, the difference between weight of pupae and effect of egg density on larval growth in the tested substrates are indicative of the greater value of human excrements for development of house flies than quail droppings. This is also reflected in the dynamics of larval growth in these substrates.

Thus, there was uniform weight gain on the 1st and 2d days of larval development on quail droppings (no reliable differences in relative gain; see Table). Relative gain on the 2d day of development on human excrements was almost 4 times greater than on the 1st day (see Table). Starting on the 2d day, relative gain was greater on human excrements than quail droppings, i.e., larvae grew more intensively on human excrements.

After growth stopped, the prepupa lost about 17% of maximum weight of third instar larvae when grown on human excrements and about 19% when raised on quail droppings. The pupa lost about 6% of the prepupal weight on human excrements and about 25% of maximum third instar larval weight; the mean figures for quail droppings were 12 and 34%, respectively. The difference in weight loss by the pupae developing in quail droppings and human excrements could be due to the difference in moisture content of the tested substrates at

the time of pupation. There are data to the effect that medium moisutre has an appreciable effect on weight loss in pupae of Lucilia flies [9].

The significant weight loss when the larvae at the third instar change into the prepupa stage is related to discontinued feeding and emptying of the intestine. Weight loss at the pupal stage is attributable both to energy expended for respiration during morphogenesis and evaporation of moisture from the surface of the pupa.

Our data revealed that not only human excrements (preferred substrate for the house fly), but quail droppings can be used to produce biomass of fly larvae. Use of this route of utilization of waste in BLSS in order to recover a good quality of feed biomass for the animal part of the system will increase the extent to which the system is closed.

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CLINICAL STUDIES

UDC: 612.858.76.014.45.017.2

SHORT-TERM ACOUSTIC ADAPTATION AS A CRITERION OF RESISTANCE OF THE AUDITORY SYSTEM TO NOISE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 6, Nov-Dec 82 (manuscript received 23 Mar 82) pp 76-79

[Article by A. S. Rozenblyum]

[English abstract from source] The typological features of short-term acoustic adaptation (STAA) and its applicability for evaluating the hearing resistance to noise effects were investigated in those working in a noisy environment. The experiments were carried out on 29 subjects with normal hearing and 46 patients with neurosensory hypoacusis, including 25 patients with occupational hypoacusis. The STAA magnitude was evaluated as the difference between the hearing threshold of the 20 msec signal paired with a preceding adapting signal or without it. The duration of the adapting signal was in the range 20-1000 msec and its intensity was 40 dB over the hearing threshold. The signals were applied at 50 msec intervals. The STAA value was 5-25 dB in 90% normal subjects. In the patients with occupational hypoacusis, the hearing degradation increased as STAA declined. The patients with common neurosensory hypoacusis did not show such a relationship. It is recommended to use STAA as a measure of man's hearing resistance to noise effects.

[Text] It is known that prolonged work under noisy conditions most often leads to development of hypoacusis. However, occupational hypoacusis appears and d develops differently in different people. This warranted the assumption that the human auditory system has individual resistance to noise. Detection of the risk group among individuals working in the presence of industrial noise is an important problem, which pertains to many specialties, including pilots and cosmonauts.

One of the important properties of the auditory system is its ability to adapt to a brief sonic stimulus--short-term acoustic adaptation (STAA). Acoustic stimulation is used to test STAA, as well as long-term adaptation, and a temporary shift of hearing threshold (THT) is demonstrated after such stimulation.

Many factors that have a deleterious effect on the organ of hearing (noise, ototoxic agents) affect primarily the peripheral parts of the auditory system. For expressly this reason, determination of individual resistance of this system should be based on investigation of phenomena that are related to peripheral organs of hearing.

In recent years, it was determined that there is a link between STAA and the peripheral parts of the auditory system [1, 2], for which reason it was interesting to investigate the possibility of using STAA to assess the resistance of the ear to noise.

Methods

STAA was studied using a special electroacoustic device. A G3-33 generator served as the source of signals, and from it signals were delivered to a time shaper (electronic key). The voltage of the signal at the output of the key was monitored constantly with a lamp voltmeter, and it constituted 3 V. Electricity from the key output passed to attenuators with 1-dB graduation. The signals were fed to TD-6 telephones with nonuniform frequency characteristics, not exceeding ±6 dB in the frequency range of 200-6000 Hz. The tests were conducted with adapting signals lasting 20, 50, 100, 500 and 1000 ms. Time of build-up and decline of the signal constituted 2 ms for a 20-ms signal and 5 ms with others. The test signal lasted 20 ms, with 2 ms duration of build-up and decline. Most of the readings were taken at 20, 50 and 100 ms intervals between signals. The frequency of the adapting and test signals was 2000 Hz. The adjustment [set?] method was used to determine the threshold of the test signal. The subject had to adjust the intensity of pairs of signals as they were delivered, while in a chamber, until he reached the threshold level of the test signal. THT (in dB) was defined as 20 log (P_A/P_S), where P_A is the threshold sonic pressure of test signal delivered after the adapting one and P_S is the threshold sonic pressure of the test signal in quiet conditions (without adapting signal).

One series of studies involved 3-6 successive readings. We took the arithmetic mean of these readings as the test signal threshold. For one reading, the subject had to listen to 20 to 40 pairs of signals. In all, more than 1500 readings were taken.

These studies were conducted on 29 individuals with normal hearing and 49 patients with functional impairment of the sound-perceiving system, in 25 of home neurosensory hypoacusis was caused by noise and in the others by infectious diseases, vascular disorders, etc. Over half of the patients with occupational neurosensory hypoacusis (16) were cast cleaners. In addition, the group included shipwrights (4 people) and blacksmiths (5). According to the existing classification [3, 4], the patients with occupational hypoacusis were distributed as follows: there were 2 patients with signs of noise effects on the auditory system, 11 with hypoacusis grade I, 8 with grade II hypoacusis and 4 with grade III. The subjects ranged in age from 33 to 54 years (average 46.6 years).

Results and Discussion

When starting the study of STAA, it was necessary, first of all, to determine whether this procedure of measurement is difficult for the subject, as compared to ordinary determination of the threshold of a brief test signal (20 ms) in quiet conditions (without adapting signal). For this purpose, we calculated the mean standard error of an isolated reading in three subjects chosen at random in the group with normal hearing. Calculations made on the basis of

15-30 readings for each of the subject in quietness revealed that the standard mean error constituted 2.8-3.5 dB. With measurement of signal in a pair with an adapting signal, mean standard error of a single reading was lower (2.1-2.5 dB). Similar data were obtained in comprehensive readings taken on one subject by other authors [5]. This enabled us to conclude that the actual procedure of measuring the threshold of a short signal with use of an adaptive factor is performed just as accurately by subjects as ordinary measurement in quiet conditions.

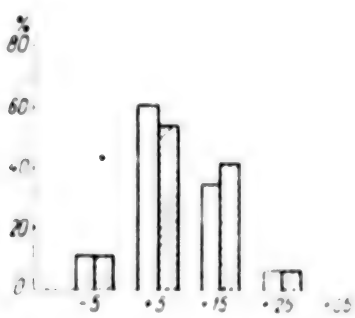

Figure 1.
Histograms of distribution of THT with STAA in individuals with normal hearing. Here and in Figure 2: speech frequency 2000 Hz, intensity 40 dB above audibility threshold; interval between signals 50 ms.
X-axis, THT (in dB above audibility threshold measured in quietness); y-axis, number of cases (%). White columns--empirical frequencies, crosshatched--theoretical.

We studied the typological distinctions of STAA in 29 subjects with normal hearing. THT was measured with adapting signals lasting 20, 50, 100 and 1000 ms. The interval between signals was 50 ms. The intensity of the adapting signal was 40 dB above hearing threshold.

Analysis of the results involved comparison of STAA obtained for 20 and 50 ms to values obtained with longer adaptive signals (100, 500 and 1000 ms). A comparison of these two groups using the criterion of Kolmogorov-Smirnov (λ criterion) revealed that there are r om differences between groups ($\lambda = 0.84$). This enabled us to combine the results obtained with signals differing in duration into one group.

Relationship between STAA and hearing impairment ($\bar{X} \pm m$) in individuals with hypoacusis caused by noise

Tested group	Work tenure, years	THT, dB	Average hearing loss, dB
1	16.3	5.6±0.9	39.5±2.6
2	16.7	14.5±0.9	30.8±2.8
3	14.3	22.7±2.0	19.2±1.3

Note: $P_{1-2}<0.05$; $P_{1-3}<0.001$; $P_{2-3}<0.001$

These THT measurements revealed that it varies from subject to subject over a wide range, and this applies both to mean THT and THT with exposure to signals of different duration. Apparently, there are different typological forms of manifestation of STAA in individuals with normal hearing, and they determine the difference in THT. In order to determine how large is the discrepancy between empirical and normal distribution, we estimated a theoretical series by equalizing the empirical variation curve according to normal law. Comparison

of empirical and theoretical series of distributions is illustrated in the form of distribution histograms in Figure 1. We took the result of measurement of THT in one subject for a given duration of adaptive signal as an individual case. According to the data illustrated in Figure 1, THT of 5-15 dB is observed more often in subjects with normal hearing, less often it is 20-25 dB. In only a few cases were minimal (less than 5 dB) or maximal (over 25 dB) THT values demonstrable. A simple calculation revealed that THT was in the range of 5-25 dB for 90% of the subjects.

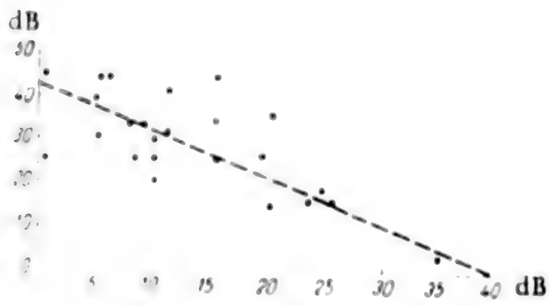

Figure 2.
Degree of hypoacusis as a function of THT with STAA in patients with occupational hypoacusis

Since STAA could lead to a rather significant decrease in perceived volume of an acoustic signal, the hypothesis was expounded that STAA could have a protective function against noise. In view of the fact that different subjects presented different STAA values, these typological distinctions could play some part in onset and development of occupational hypoacusis. In this respect, investigation of STAA in patients with neurosensory hyp - acusis was of special interest, in the cases where hearing impairment was caused by industrial noise.

Figure 2 illustrates the results of calculating mean hearing loss in the range of speech frequencies (500-2000 Hz) in some patients with occupational hypoacusis as a function of STAA. Each point on this figure is the result of 15-20 readings on the same patient. We see that the degree of hearing impairment gradually diminishes as the value of STAA grows. In cases where STAA exceeded 20 dB hearing impairment had minimal values (5-25 dB). The coefficient of correlation of this function is 0.64, which corresponds to a 0.001 level of significance.

The Table lists averaged results of measuring extent of hearing impairment in patients with neurosensory hypoacusis caused by industrial noise. The distribution in groups is based on STAA: for the 1st group STAA constituted 0 to 10 dB, for the 2d 11 to 20 dB and for the 3d group of subjects over 20 dB. Average work tenure for each group is also listed. This table shows that maximum loss of hearing corresponded to groups with lowest STAA. These differences in hearing impairment of different groups were statistically reliable.

We failed to demonstrate such a dependence of degree of hearing impairment on STAA in patients with neurosensory hypoacusis caused by ordinary factors other than noise (toxic damage to hearing, vascular diseases, etc.). Thus, hearing impairment constituted 31.0±6.6, 35.0±7.8 and 35.2±8.6 dB in patients with STAA of 6.3±0.9, 11.5±0.8 and 25.3±2.7 dB, respectively.

Thus, a relationship between severity of hearing impairment and STAA was noted only in patients with occupational hypoacusis caused by noise, and the lower the value of STAA the greater the hypoacusis in subjects with relatively equal work tenure.

Our data warrant the conclusion that STAA is a parameter that could be used as a gauge of resistance of the human auditory system to noise and, in particular, to predict occupational hypoacusis.

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METHODS

UDC: 616-073.731-073.96-035.7+612.014.422-08

AMPLITUDE DISTORTIONS ON RHEOGRAMS WHEN RECORDED SIMULTANEOUSLY ON SEVERAL CHANNELS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 6, Nov-Dec 82 (manuscript received 6 Nov 81) pp 80-82

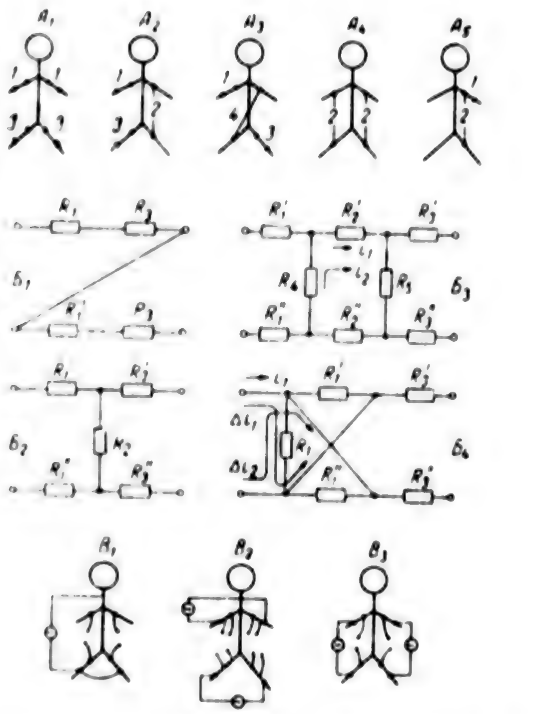
[Article by R. Kh. Tukshaitov and D. G. Maksimov]

[Text] Rheography is one of the important methods for indirect evaluation of circulation and external respiration [1-4]. This method is based on determination of electric resistance of the tested part of the human or animal body to high-frequency electric current [5, 6]. In Soviet medicine and physiology, different types of rheographs are used for this purpose: bipolar, four-channel, without frequency separation of channels (4RG-1A); bipolar, with frequency separation of channels (RG-4-01), and tetrapolar, two-channel, with one generator for both channels (RPG-2-02). The instrumental margin of error is ±5%; however, overall error factor could reach 10-20% and, in some cases, even more [6, 7]. One of the causes of such error factors could be the influence of rheographic leads on one another with multichannel recording.

Our objective here was to define the conditions of appearance and magnitude of possible distortions of rheogram amplitudes when recorded simultaneously on two channels using the above-mentioned instruments.

Methods

Studies were conducted on 12 rabbits using electric models (see Figure, E_{1-4}), as well as 18 essentially healthy male subjects, using 3 types of Soviet rheographs: 4RG-1A, RG-4-01 and RPG-2-02. Rheograms were recorded for rabbits using needle electrodes in leads from the front and hind legs (see Figure, A_{1-5}), as well as trunk and head. In the men, analogous leads were recorded by means of standard circular electrodes and, on the head, standard round electrodes. The rheograms were recorded for 3-5 respiratory cycles with monitoring of frequency and depth of respiration (perimetric resistor sensors) with the automatic tracer of the Siemens electrocardiograph (mingographs 42 and 81). Each tracing was repeated 3 to 10 times. Analysis of the tracings included determination of base interelectrode resistance (R_b), mean amplitude of 3-dimensional [volumetric?] rheogram (ΔR) and amplitude of calibration signal (0.1 Ω). To improve accuracy of determination of R_b, we connected a digital F-4202 voltmeter to the indicator or dial of the rheographs, calibrated in ohms for the R-33 resistance box. Distortion of base resistance



Diagrams of location of electrodes in subjects and rabbits (A_{1-5}, B_{1-3}), as well as equivalent electric models (Б$_{1-4}$), to investigate possible distortions of base resistance and pulse or respiration amplitude on rheograms when recorded simultaneously on two channels

and amplitude of pulse or respiration on the rheograms was determined from the difference in the above parameters before and after connecting the second lead. For the sake of convenience, these differences were expressed as percentage of values obtained with use of one lead. In statistical processing of the results, we determined mean distortion and scatter ($M \pm m$), as well as reliability of changes according to Student (P).

Results and Discussion

Use of the 4RG-1A rheograph to test ohmic resistance of electric equivalents simulating different distribution of current in two biosegments (R' and R") revealed that there was now reciprocal influence of rheographic channels in the presence of simple galvanic link between electric equivalents (see Figure, Б$_{1-2}$). Reciprocal effects between channels were found when simulating common current-carrying circuits (see Figure, Б$_3$), and they depended on the "polarity" of connection of the generator circuit of the rheograph. The same phenomenon was observed upon simulating superposition of two electrodes referable to different leads (see Figure, Б$_4$). In the case of current in the same direction in both circuits ($\phi = 0°$), there was an increase in ohmic resistance, and with different directions ($\phi = 180°$) it decreased. The amplitude of the calibration signal changed in the opposite direction from the changes in ohmic resistance of the model.

Use of the 4RG-1A rheograph for simultaneous recording of rheovasograms of the right and left arm or right and left leg (see Figure, A_1) or with one lead from the arm and leg and another lead only the arm or leg (see Figure, A_{2-3}) was not associated with reciprocal influence of channels, nor was there an effect in these leads of change in "polarity" of connecting electrodes to the high-frequency generator. Analogous results were obtained with rabbits, even when the rheovasogram was recorded on one channel and the rheopneumogram in the lead from the front and hind legs on the other (see Figure, A_{2-3}). However, with simultaneous connection of two leads from the front and hind legs (see Figure, A_4), there was distortion of base resistance, which depends on "polarity" of connecting electrodes and their location on each half of the body. With inphase passage of current in both halves of the body, R_b increased by a mean of 14±1.7% ($P<0.01$), and with counterphase connection of current it decreased by about the same value.

Reciprocal influence of channels for two leads from the left and right half of the body (see Figure, A_4) affected amplitude of respiratory waves (ΔR_{res}) even more in rabbits than R_b, reaching 21±3.3%, and just as in the case of R_b, the error of measurement of ΔR_{res} was related to "polarity" of connecting the electrodes and their location on each half of the body. With decrease in distance between electrodes for each lead (L) and relative increase in distance between leads (L), error of measurement of ΔR_{res} diminished. With L = 1, ΔR_{res} error constituted 14±2.3% and with L = 1.51 it decreased to 5±0.7%. In the latter case, the error of measurement of R_b did not exceed 1-2%.

Investigation on rabbits of possible distortions with simultaneous recording of two rheoencephalograms from the left and right half of the head in the frontomastoid or fronto-occipital leads revealed that they constituted a mean of 7.4±0.9 and 13±1.7%, respectively ($P<0.01$). Distortions of base resistance constituted 3-4 and 6-8%.

The results of investigating in humans the possible distortions when combining two electrodes referable to arm-arm and arm-leg leads (see Figure, A_5) revealed that the margin of error constituted a mean of 28±0.4% for base impedance and 33±3.4% for the pulse rheogram. Spreading the combined electrodes over 10 cm reduced error to 4-6%.

When using the RG-4-01 rheograph, combination of two adjacent electrodes in the arm-arm and arm-leg leads (see Figure, A_5) was not associated with distortion of R_b and ΔR. We failed to demonstrate reciprocal influence of channels either when we recorded simultaneously on the same rheograph the two fronto-occipital leads from the left and right halves of the head, as well as two arm-leg leads from the right and left halves of the human or rabbit body (see Figure, A_4). However, when we used two RG-4-01 rheographs simultaneously, to record rheograms of the left half of the body on one and the right half on the other in the arm-leg lead (see Figure, A_4) distortions of R_b and ΔR appeared, which were analogous to those observed with the 4RG-1A rheograph.

When we used the RPG-2-02 rheoplethysmograph for simultaneous recording of two rheovasograms from the left and right halves of the body (see Figure, B_1), as well as two RPG-2-02 rheoplethysmographs, recording two rheograms of the arms with one and two rheograms of the legs with the other (see Figure, B_2), we failed to detect reciprocal influences of the channels. However, with simultaneous use of two RPG-2-02 rheoplethysmographs to record rheovasograms of the left half of the body in the arm-leg lead with one of them and the same lead from the right half with the other (see Figure, B_3) there were changes in ΔR constituting a mean of 16±3.3%. R_b changed by 1-5%. As was the case with use of the 4RG-1A rheograph, the changes in ΔR and R_b were related to "polarity" of electrode connection, their location on both sides of the body, as well as individual distinctions of rheoplethysmographs. In some cases, when two RPG-2-02 were used to record the leads illustrated in the Figure, B_3, interference of the pulsation type appeared, which blocked the useful signal.

With simultaneous recording using the 4RG-1A rheograph of two leads from parts of the body at some distance from one another, when the area of propagation of current from one lead was not overlapped by the other, there were no amplitude distortions on the rheograms. In the presence of reciprocal influence of current from two leads (for example, when recording rheograms of symmetrical

parts of the body, when the distance between electrodes for at least one lead is greater than the distance between leads), distortions appear in base resistance and amplitude of rheograms on the order of 5-33%. Analogous distortions occur under similar conditions with simultaneous use of two RG-4-01 rheographs or two RPG-2-02 rheoplethysmographs. If, however, one RPG-2-02 or one RG-4-01 rheograph is used for simultaneous recording of two rheographic leads, there are no rheogram amplitude distortions, even if the regions of propagation of current from two leads overlap or there is superposition of two electrodes in adjacent leads.

These results warrant the recommendation that, when working with the 4RG-1A rheograph, one should see to it that the distance between adjacent leads is more than 1.5 times greater than the distance between electrodes for each lead. The same rules apply for simultaneous use of two RG-4-01 rheographs or two RPG-2-02 rheoplethysmographs.

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BRIEF REPORTS

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EFFECT OF SPACEFLIGHT ON LIPOGENESIS AND LIPOLYSIS IN RATS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 6, Nov-Dec 82 (manuscript received 24 Jul 81) pp 82-83

[Article by N. Skottova, L. Macho, M. Palkovic and R. A. Tigranyan (CSSR and USSR)]

[Text] When rats were flown for 22 days in space aboard Cosmos-605 biosatellite, they weighed less and there was a decrease in fatty tissue subcutaneously and in other fat reservoirs [1]. Studies conducted aboard Cosmos-605, Cosmos-690 and Cosmos-782 revealed that prolonged exposure of rats to weightlessness was associated with some changes in lipid metabolism [2-4]. Our objective here was to investigate the effect of spaceflight on activity of several enzymes involved in fat metabolism.

Methods

These studies were conducted on male Wistar-SPF (Bratislava, CSSR) rats flown for 18.5 days in space aboard Cosmos-936. The characteristics of experimental conditions and designations of animal groups were given in [5]. We assayed lipogenetic enzyme activity in the liver--ATP citrate lyase (EC 4.1.3.8) [6] and malate dehydrogenase (EC 1.1.1.40) [7]; in adipose tissue we determined the activity of lipoprotein lipase (EC 3.1.1.3), as well as basal and norepinephrine-stimulated lipolytic activity of adipose tissue; lipase and lipolytic activity of adipose tissue was expressed in micromoles of NEFA [nonesterified fatty acids], which was determined by a method published in [8]. Protein content was assayed by the method described in [9].

Results and Discussion

ATP citrate lyase activity in the liver of rats exposed to weightlessness was lower 6 h after landing than in animals of the vivarium control. In rats submitted to artificial gravity aboard the biosatellite, it increased the levels found in vivarium control rats. However, these changes were not reliable. At the same time, the activity of this enzyme was reliably greater in both flight groups of rats, as compared to the corresponding groups in the synchronous experiment. In turn, activity of the enzyme was reliably lower in animals used in the synchronous experiment than in the vivarium control. ATP citrate lyase activity in the liver of experimental groups of rats did not differ from the vivarium control 25 days after landing (Figure 1).

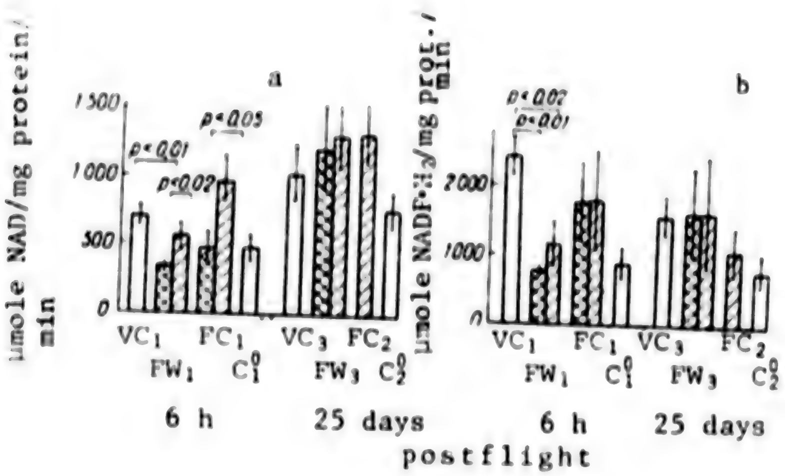

Figure 1. ATP citrate lyase (a) and malate dehydrogenase (b) activity in rat liver ($M \pm m$; 6 animals). Crosshatched columns--synchronous experiment; striped--flight experiment*

Key, for this, Figures 2 and 3:

VC) vivarium control
FW) flight group, weightlessness
FC) flight group, centrifuge
C) centrifuge experiments

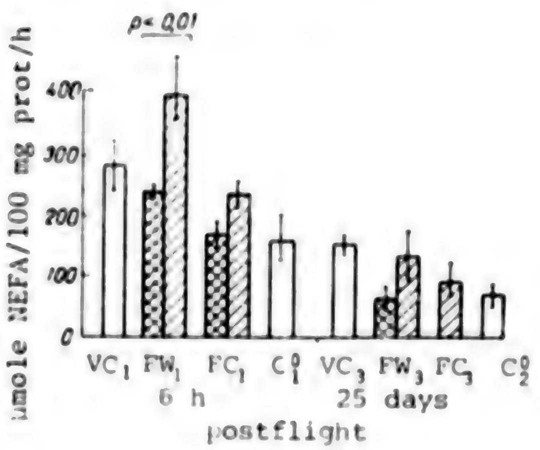

Figure 2.
Lipoprotein lipase activity in rat adipose tissue

Malate dehydrogenase activity in the liver of flight rats and animals in the corresponding group of the synchronous control was lower 6 h after the experiment than in the vivarium control animals. In rats submitted to centrifugation in flight, as well as those in the corresponding synchronous experiment group, the activity of this enzyme did not change. The activity of this enzyme in the liver of animals referable to experimental groups did not differ 25 days after the spaceflight from activity in vivarium control rats (see Figure 1).

Lipoprotein lipase activity in adipose tissue of flight animals exposed to weightlessness was increased 6 h after the biosatellite returned to earth; but this increase was reliable only in comparison to parameters of the corresponding group in the synchronous experiment. Artificial gravity prevented increase in activity of this enzyme. Lipoprotein lipase activity in adipose tissue of animals in all groups did not differ 25 days after the flight from activity in vivarium control rats (Figure 2).

*Translator's note: Russian caption describes "boldface" and "light" crosshatching, which is not discernible; it is assumed the intent was to distinguish between crosshatched and striped.

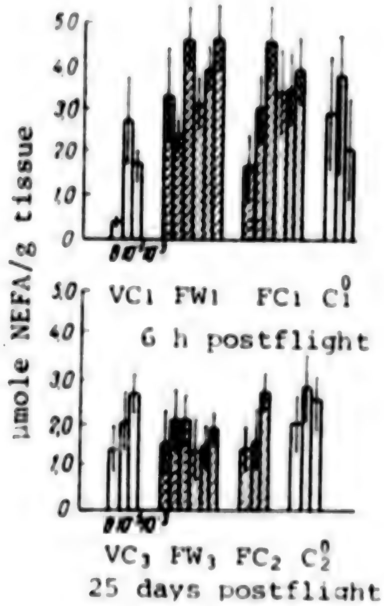

Figure 3.
Basal (B) and norepinephrine-stimulated (10^{-5} and 10^{-3} M) lipolytic activity of rat adipose tissue

Basal lipolysis of adipose tissue was increased 6 h after the experiments in the flight and synchronous experimental groups, as compared to the vivarium control; no differnece was demonstrable between flight and synchronous groups with regard to basal lipolysis. When norepinephrine was added in vitro, it increased lipolysis only in vivarium control rats; basal lipolysis was already so high in flight animals and rats in corresponding groups of the synchronous experiment that norepinephrine did not increase it. Basal and norepinephrine-stimulated lipolysis diminished to the level of the vivarium control 25 days after landing in flight groups and groups in the synchronous experiment (Figure 3).

Our results indicate that spaceflight is associated with changes in lipid metabolism in rats. There is increased lipogenesis in the liver and incorporation of fatty acids and triglycerides of adipose tissue, but no change in basal and norepinephrine-stimulated lipolysis of fatty tissue--release of fatty acids into blood. Apparently, one can partially prevent the changes in lipid metabolism by using artificial gravity. Such changes in lipid metabolism of rats in the flight and synchronous experiments, as compared to animals in the vivarium control, are indicative of the possible effect of hypokinesia on lipid metabolism.

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HORMONE CONCENTRATION IN RAT BLOOD PLASMA AFTER FLIGHT ABOARD COSMOS-936 BIOSATELLITE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 6, Nov-Dec 82 (manuscript received 24 Jul 81) pp 84-87

[Article by R. A. Tigranyan, L. Macho, R. Kwetnansky and N. F. Kalita (USSR and CSSR)]

[Text] Investigations of vital physiological systems of animals, which were conducted in experiments aboard biosatellites of the Cosmos series showed that it is possible for mammals (rats) to adapt to long-term weightlessness. At the same time, these experiments revealed that there were several signs of activation of the endocrine system, namely, the hypothalamo-hypophysio-adrenocortical part, which appeared under the effect of the set of spaceflight factors and rapid change to earth's gravity [1, 2]. Our study of blood plasma corticosterone concentration in rats after termination of experiments aboard Cosmos-605, Cosmos-690 and Cosmos-782 revealed that corticosterone level is elevated in the first few hours after the spaceflight. Then the plasma corticosterone level drops and is already considerably lower than the control level 24 h postflight [3-5]. The spaceflight aboard Cosmos-782 did not cause any significant changes in the hormonal status of animals (according to results of assaying blood ACTG, prolactin, thyrotropic, follicle-stimulating, luteinizing and melanocyte-stimulating hormones [6]). The data were indicative of the need to continue studies of the effects of spaceflight factors on endocrine reactions in animals. We submit here the results obtained after the flight aboard Cosmos-936.

Methods

The studies were conducted on male Wistar-SPF rats (Bratislava, CSSR) flown in space for 18.5 days aboard Cosmos-936. Experimental conditions were described in [7]. We assayed blood plasma concentration of ACTH, testosterone, insulin, thyrotropic hormone (TTH), thyroxine (T_4) and triiodothyronine (T_3) by the method of radioimmune analysis and corticosterone (B) content [8]; we also examined adrenal B production [9].

Results and Discussion

Plasma ACTH level in animals examined 6 h after the spaceflight did not differ from the vivarium control and corresponding groups in the synchronous experiment.

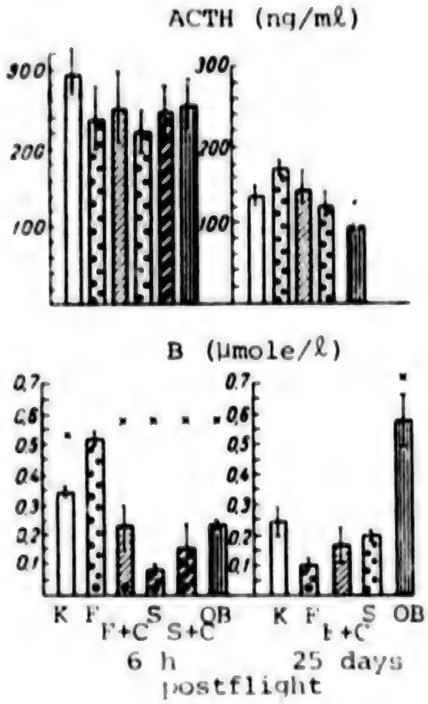

Figure 1.
ACTH and B concentration in rat blood plasma. * shows reliability P<0.01 for OB as compared to the K group, in other instances as compared to the F group. Here and in Figures 2-4 mean data (M±m) from 6 readings are given.

Key for Figures 1-4:
- K) control
- F) flight
- F+C) flight in centrifuge
- S) synchronous experiment
- S+C) synchronous experiment in centrifuge
- OB) angular accelerations

It should be noted that plasma ACTH concentration was considerably higher in all groups of animals than is usually observed in animals not submitted to stress [10]. In flight animals, 25 days after termination of the experiment, plasma ACTH level also failed to differ from the level of this hormone in control groups, and a low level was noted only in the OB (angular accelerations) group (Figure 1).

Conforming to the unchanged plasma ACTH level, immediately after landing the flight animals showed no changes in production of B by the adrenals in vitro, as compared to control groups. Adrenal reaction to ACTH was also the same in flight and control groups (Figure 2).

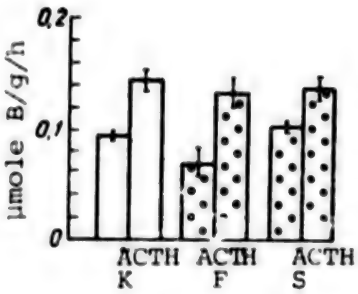

Figure 2.
Adrenal production of B without and after stimulation of ACTH

Elevation of B in plasma was found after flight in weightlessness, as compared to rats submitted to artificial gravity (AG) in flight and those in control groups. Plasma B level in flight animals 25 days after landing did not differ from the control; concentration of B in plasma of the OB group was increased (see Figure 1).

Blood plasma testosterone level did not change in flight animals immediately after the flight, as compared to control animals. We also failed to demonstrate a difference in these parameters after the readaptation period on the ground.

Plasma insulin level was higher immediately after the flight than in control groups of rats; it did not change when rats were exposed to AG in flight. After the readaptation period, blood plasma insulin levels were low in both flight groups, as compared to control groups of animals (Figure 3).

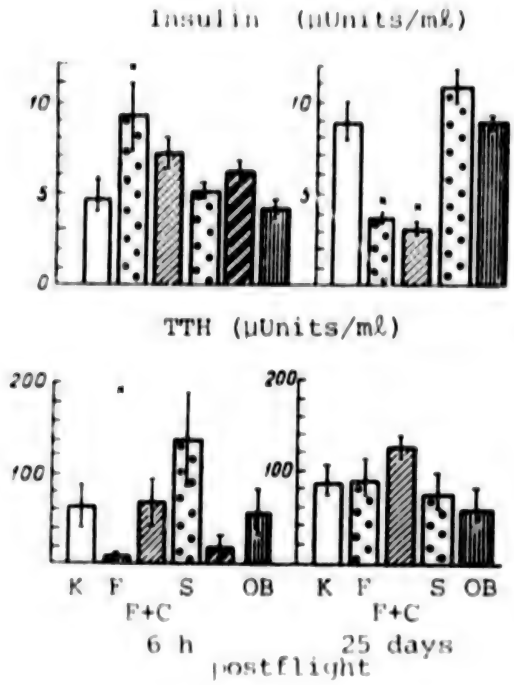

Figure 3.
Insulin and TTH concentration in rat blood plasma

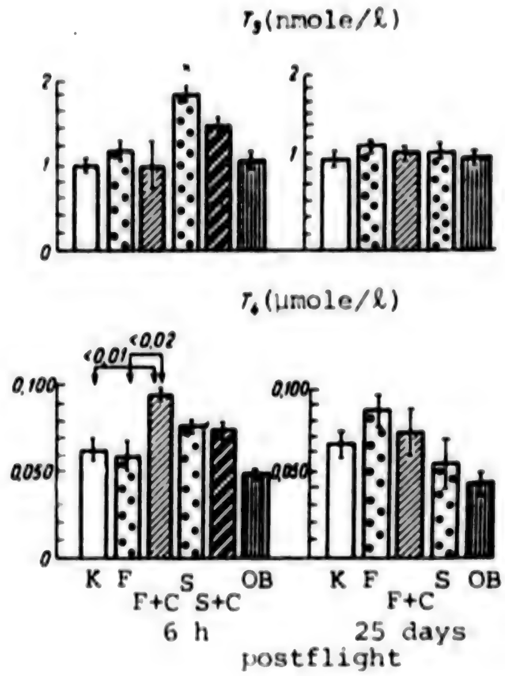

Figure 4.
Concentration of T_3 and T_4 in rat blood plasma

In Figures 3 and 4, × shows reliability P<0.01, as compared to the K group.

We found a significant decline of blood plasma TTH after flight in weightlessness, as compared to rats submitted inflight to AG and control groups. TTH level in plasma of flight animals 25 days after landing did not differ from the control level (see Figure 3).

Immediately after the flight, we observed a significant increase in blood plasma T_4 concentration in rats submitted to AG during the flight, as compared to the vivarium control and level of this hormone in flight animals submitted to weightlessness. Plasma T_4 level 25 days after termination of the experiment in animals of all tested groups did not differ from the vivarium control (Figure 4).

We failed to demonstrate changes in blood plasma T_3 content in all tested groups, either 6 h or 25 days after termination of the experiment, with the exception of reliable decrease in concentration of this hormone 6 h after terminating the synchronous experiment (see Figure 4).

Analysis of our data revealed an elevated ACTH level in blood plasma of all groups of animals, as compared to animals not submitted to stress. This could be indicative of presence of stress, which was most probably related to euthanasia conditions. We failed to demonstrate any significant changes in plasma ACTH level in all tested groups, which is consistent with the findings obtained in the experiment aboard Cosmos-782 biosatellite [6]. The low plasma ACTH level in the OB group of animals coincided with elevated plasma B level in these animals. In all likelihood, the elevated level of B had an inhibitory

effect on ACTH secretion via the feedback system. In view of the fact that adrenal production of B did not change after the spaceflight, changes in breakdown of this hormone in tissues are probably also involved in the elevation of plasma B level in flight animals submitted to weightlessness.

The increased insulin concentration in blood of flight animals immediately after the flight and decrease at the second examination could be related to changes in blood glucose content in these animals. It should be noted that an elevated insulin concentration had also been observed immediately after the mission of cosmonauts on the Skylab program [11].

A reliable increase in plasma T_4 concentration was demonstrated only in rats exposed to AG; plasma T_3 concentration did not change in flight rats, while the concentration of TTH was significantly diminished. It should be noted that significant elevation of blood TTH and T_4 had been found in cosmonauts after flight [11, 12]. The causes of such difference in reaction of the human and rat thyroid in the postflight period are not clear.

Thus, our studies revealed that the level of tested hormones in plasma of flight animals did not change appreciably, with the exception of TTH and B. Use of AG aboard the biosatellite normalized the plasma concentrations of B and TTG in flight animals.

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EFFECT OF STEADY MAGNETIC FIELD ON HUMAN LYMPHOCYTES

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 6, Nov-Dec 82 (manuscript received 30 Apr 80) pp 86-87

[Article by M. Mileva, B. Ivanov, M. Bulanova and T. Pantev (People's Republic of Bulgaria)]

[Text] The question of genetic effect is still unanswered. On the one hand, cytogenetic disturbances have been described, which were caused by a steady [constant] magnetic field (SMF) [1-7] and on the other hand there are data indicative of absence of changes [8-11].

All this served as grounds to conduct this study.

Methods

Whole human blood was submitted in vitro to SMF (magnet No 11007, type 1, pole diameter 7.5 cm, interpole distance 7 cm) with induction of 0.3 T, at a temperature of 37°C, for 15, 30, 45, 60, 90, 120, 180, 240, 300 and 360 min. Blood was cultivated for 48 h by the method of Evans. Blood cultivated under the same conditions but without exposure to SMF served as a control. We counted chromatid and chromosome fragments, aberrant cells and total aberrations. We examined at least 400 cells in each experimental variant. Differences with $P<0.05$ were considered reliable.

Results and Discussion

As can be seen in the Table, exposure to SMF for different periods of time did not elicit statistically reliable increase in chromosome aberrations in human peripheral blood lymphocytes.

Metaphase analysis of Crepis capilaris cells revealed that SMF (9 kOe, 200 Oe/cm) for 2 days did not induce chromosome aberrations [9]. Nor were any changes demonstrated in roots of beans, onions [2] and L-fibroblasts of subcutaneous tissue of mice and Chinese hamsters [8]. The obtained data are indicative of absence of cytogenetic effect of SMF. The level and spectrum of chromosome aberrations did not exceed the values for spontaneous chromatic fragments in cultures. Cytogenetic analysis of DEDE cells of the Chinese hamster revealed a mild mutagenic effect of SMF [4]. Chromosomal aberrations were also demonstrated after exposure (5 min) of garlic roots [6]. It is difficult to

compare the moderate mutagenic effect observed by some authors [1-7] to the data of Tuaneva et al. [5]. They observed a drastic increase in number of chromosome aberrations in human peripheral blood lymphocytes after 30-s exposure to SMF with 0.175 T. The number of changes increased with increase in exposure time from 30 s to 30 min. The high mutagenic effect of SMF established by these authors depends, to some extent, on the drastic increase in number of chromosomal disturbances of the "geps" type [?], which we did not take into consideration. The nature of these changes is still not entirely clear. Some cytogeneticists do not consider them to be chromosomal aberrations, in spite of some indications that the number of such disturbances depends on mutagen dosage.

Number of chromosomal aberrations after exposing human lymphocytes to SMF

SMF EXPOSURE TIME, MIN	NUMBER OF CELLS EXAMINED	NUMBER OF CELLS WITH ABERRATIONS	CHROMATID FRAGMENTS, %	CHROMOSOME FRAGMENTS, %	TOTAL ABERRATIONS, %
CONTROL	600	1,49±0,5	0,83±0,3	0,66±0,3	1,49±0,6
15	600	0,83±0,8	0,33±0,3	0,50±0,0	0,83±0,8
30	600	1,82±0,6	0,66±0,3	1,16±0,3	1,82±0,7
45	600	1,16±0,9	0,16±0,3	1,00±0,8	1,16±0,9
60	600	1,16±0,3	0,50±0,0	0,66±0,3	1,16±0,3
90	600	1,16±0,3	0,33±0,3	0,83±0,3	1,16±0,3
120	600	0,99±0,6	0,66±0,3	0,33±0,3	0,99±0,6
150	600	1,66±0,3	0,66±0,3	1,00±0,6	1,66±0,3
180	600	1,33±0,0	1,00±0,3	0,33±0,3	1,33±0,0
240	400	1,50±0,6	0,50±0,0	1,00±0,6	1,50±0,6
300	400	2,50±1,0	1,25±0,5	1,25±0,5	2,50±1,0
360	400	1,25±0,5	0,50±0,0	0,75±0,5	1,25±0,5

Perhaps, the contradiction between different authors about the mutagenic effect of SMF on chromosomes is related to dissimilar exposure conditions, which are not always taken into consideration. Apparently, this also applies to the cited works. Further studies of effects are needed, as related to field intensity, gradients, exposure time and other factors.

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CHANGES IN SOME BIOCHEMICAL PARAMETERS OF BLOOD AS A FUNCTION OF PROGRAM OF ACCELERATIONS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 6, Nov-Dec 82 (manuscript received 24 Aug 81) pp 87-89

[Article by J. Domaczuk (Polish People's Republic)]

[Text] Resistance to accelerations can be characterized by both the maximum acceleration achieved and duration of exposure to a specified level of accelerations.

As a rule, resistance to accelerations is evaluated with the use of centrifuges. As we know, accelerations elicit hemodynamic disorders, which result in hypoxia [1, 2]. Under such conditions, there is also impairment of biochemical processes [3-7].

Our objective here was to examine the end metabolic products in animals, in whom accelerations elicited bradycardia upon reaching maximum endurance, due to both duration of exposure ("time program") and magnitude of accelerations ("linear program").

Methods

This study was conducted with Wistar rats weighing 180-200 g. The animals were divided into 3 groups of 11 in each. The first group served as a control; the second group was submitted to +Gz accelerations on a centrifuge, on a "linear program" with build-up of accelerations at the rate of 0.2 G/s up to the time that bradycardia appeared. The third group was tested on the "time program," with accelerations of +10 Gz, also used until bradycardia appeared. The EKG was recorded throughout the period of rotation. Upon appearance of bradycardia, rotation was stopped, and we immediately took blood from the heart for biochemical analyses. We determined blood serum pH, pCO_2, glucose, lactic and pyruvic acid levels, fatty acids, urea, concentrations of sodium, potassium and calcium. The results were compared to those obtained in the control group of rats, which were not submitted to rotation. We also compared the results obtained in the experiments with "linear" and "time" programs of exposure.

Results and Discussion

Resistance of rats tested on the "linear program" constituted 23 to 29 G (average 25.7 G). There was not a single death in this group of animals.

Resistance constituted 15 to 58 min in the group of animals rotated on the centrifuge on the "time program" (average 27 min 35 s). Upon reaching the limit of endurance of accelerations, 6 animals of this group died. Resistance of the animals that died did not differ with regard to bradycardia from those that survived. The results of biochemical tests are listed in the Table.

Results of testing rat blood serum

PARAMETER	CONTROL	AFTER TESTING RESISTANCE ON		STATISTICAL EVALUATION, P
		LINEAR PROGRAM	TIME PROGRAM	
pH	7,00±0,42	6,79±0,113**	6,52±0,053**	<0,01
pCO_2, mm Hg	36,5±4,58	40,9±11,95	55,2±10,98**	<0,01
Glucose, mg%	75,8±4,35	105,0±16,12**	165,7±78,55**	<0,05
Fatty acids, mg%	398,0±62,9	748,0±159,5**	998,0±223,2**	<0,01
Lactic acid, mg%	20,5±1,38	24,5±3,44**	28,6±4,58**	<0,05
Pyruvic acid, mg%	1,77±0,291	2,31±0,312**	2,49±0,364**	>0,05
Urea, mg%	34,0±5,09	34,1±6,23	36,6±4,92	>0,05
Na^+, meq/l	147,7±5,3	133,4±6,0*	125,6±15,9**	<0,05
K^+, meq/l	3,8±0,48	4,3±0,50*	4,7±0,49**	<0,05
Ca^{2+}, meq/l	5,6±0,49	5,7±0,6	5,4±0,31	>0,05

Note: One asterisk shows $P<0.05$ and two asterisks $P<0.01$, in relation to control.

In the second group of animals, we found substantial decline of blood pH, Na^+ and elevation of glucose, fatty acid, lactic and pyruvic acid levels, as well as concentration of K^+ (as compared to the control). Levels of pCO_2, urea and Ca^{2+} remained at the same level as in the control group.

In the third group of animals, we demonstrated analogous changes, but they were more marked quantitatively. In addition, we found an appreciable elevation of pCO_2. Urea and Ca^{2+} levels did not change.

Comparative analysis of the results of biochemical tests on both groups revealed that blood pH and concentration of Na^+ were appreciably lower in the third group, but pCO_2, glucose, fatty acids, lactic acid and K^+ concentration were higher. The rest of the parameters (pyruvic acid, urea and Ca^{2+} content) did not differ from the second group.

Accelerations of $+G_z$ elicited inertial shifting of body fluids, mainly blood. These changes result in hypoxia, due to stasis of blood in the lower half of the body and anemia in the upper half.

Under such conditions, the rise in lactic and pyruvic acid levels, as well as decline of blood pH, become understandable. The high glucose and fatty acid levels are a consequence of hormonal mobilization as a result of sustained stress [8]. The high gradient of hydrostatic pressure inherent in $+G_z$ accelerations, as well as acidulation of the internal medium, elicit changes in permeability of the cell membrane to Na^+ and K^+ cations [7].

The experimental conditions had no effect on blood serum urea and calcium levels, although there was reason to expect an increase in urea, since

there are reports of urine retention during exposure to accelerations (as a result of intensified activity of ADH hormone) [9].

In spite of the fact that the same criteria of resistance to accelerations (i.e., appearance of bradycardia) were used for the second and third groups of animals, it was found that the third group of rats presented considerably greater biochemical changes, and there were even cases of death. This is indicative of the relatively greater burden on the body of the "time program" than the "linear" one, although in the latter case considerably higher levels of accelerations are reached.

Thus, the quantitative changes in biochemical parameters depended more on duration of exposure to accelerations than their magnitude. Let us recall that, on the "linear program," the experiment lasted 1 min 15 s, while accelerations that increased linearly reached 25 G. In the "time program," 10 G acceleration was used for 27 min 35 s.

On the "linear program," the constantly increasing accelerations rapidly reached a level exceeding the compensatory capacities of the body. This resulted in hemodynamic disorders and bradycardia. Since this develops within a relatively short time, the biochemical changes are of secondary significance in this case. At the moment of discontinuing accelerations, there was development of sinus tachycardia, and circulatory system function reverted to normal.

In the case of the "time program" of accelerations, bradycardia is a consequence of fatigue of the body and depletion of functional reserves [10]. Biochemical changes reach a critical level. Discontinuation of exposure to accelerations elicits marked mobilization of static blood, which contains a high concentration of metabolites and presents major electrolyte changes. This should be viewed as the cause, as a result of which the heart is unable to start functioning normally right after stopping rotation when using the "time program."

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10,657
CSO: 1849/2

INDEX OF ARTICLES PUBLISHED IN KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA [SPACE BIOLOGY AND AEROSPACE MEDICINE], VOLUME 16, NUMBERS 1-6, 1982

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 6, Nov-Dec 82 (signed to press 12 Oct 82) pp 89-94

[Index]

[Text] Editorials

Surveys

Stazhadze, L. L., Goncharov, I. B., Neumyvakin, I. P., Bogomolov, V. V., Vladimirov, I. V., "Anesthesia, Surgery and Resuscitation During Manned Spaceflights," 4(9).

Experimental and General Theoretical Research

Abramov, I. P., Barer, A. S., Vakar, M. I., Golovkin, L. G., Zinchenko, V. P., Filippenkov, S. N., Sharipov, R. Kh., Shchigolev, V. V., "Physiological and Hygienic Aspects of Implementation of Cosmonauts' Work in Orbital Flight," 6(16).

Ahlers, J., Tigranyan, R. A., Djatelinka, I., Schmeida, B., Toropila, M., Praslicka, M., Plasma and Tissue Lipids of Rats Following Flight Aboard Cosmos-1129 Biosatellite," 2(58).

Ahlers, J., Tigranyan, R. A., Praslicka, M., "Plasma and Tissue Lipids of Rats Following Flight Aboard Cosmos-936 Biosatellite," 2(56).

Anashkin, O. D., Belyayev, S. M., "Effect of Sydnocarb on Cardiorespiratory System During Seven-Day Water Immersion and Exercise," 6(28).

Andriyako, L. Ya., Voloshin, V. G., Degtyarev, V. A., "Distinctions of Cardiovascular Reactions in Immediate LBNP Aftereffect Period," 5(51).

Anisimov, B. V., Golubeva, T. I., Kuz'menko, G. N., Savina, V. P., "Aerosol Pollution of Airtight Habitats," 2(73).

Arslanova, R. M., Benevolenskiy, V. N., Ptitsyna, N. G., Trukhanov, K. A., "Synchronization of Cardiovascular Accidents With Physical Clocks," 3(32).

Afonin, B. V., Orlov, L. L., Kalita, N. F., Viting, T. A., Tigranyan, R. A., "Role of Hormonal Compounds in Regulation of Electrolyte Metabolism in the Presence of Emotional Stress," 3(13).

Babin, A. M., "Age-Related Distinctions of Echocardiographic Parameters of Healthy Man," 2(82).

Bayevskiy, R. M., Funtova, I. I., "Ballistocardiographic Studies During Fourth Mission Aboard Salyut-6 Orbital Station," 5(34).

Balashov, O. I., Sysoyev, A. B., Rodnikov, A. V., "Influence of Level of Mineralization of Desalinated, High-Quality Water of the Hydrocarbonate Class on Functional State of Male White Rat Gonads," 2(40).

Barer, A. S., Vakar, M. I., Vorob'yev, G. F., Iseyev, L. R., Filipenkov, S. N., Chadov, V. I., "Probability of Caisson Disease After Pressure Drop From 840 to 308 mm Hg," 1(26).

Barer, A. S., Konakhovich, Yu. G. Sholpo, L. N., "Safety Criterion for Protection of Pilot's Head Against Impacts," 5(29).

Bebutov, A. P., Danilovtsev, V. V., Krylova, N. V., "Use of Voice Communication to Study Operator Activity," 4(27).

Genin, A. M., Kotovskaya, A. R., Galle, R. R., Gavrilova, L. N., Sarkisov, I. Yu., "Human Tolerance of Rotation at Different Levels of Hypergravity," 1(70).

Govorun, R. D., Vorozhtsova, S. V., Gerasimenko, V. N., "Investigation of Cytogenetic Effects of High-Energy Charged Particles," 4(64).

Golovkina, O. L., "Human External Respiration and Gas Exchange in Acute Period of Adaptation to Immersion in Water," 3(43).

Golubeva, Ye. G., Yerofeyeva, T. V., "Dynamics of House-Fly Larva Growth on Some Forms of Organic Waste in a Biological Life-Support System," 6(74).

Grigor'yev, A. I., Dorokhova, B. R., Arzamazov, G. S., Morukov, B. V., "Ion-Regulating Function of Human Kidneys During Long-Term Spaceflights and in Model Studies," 1(29).

Gushchina, L. A., "Natural Immunity Factors as Indicators of Reactions to Heliogeophysical Factors," 6(68).

Gyurdzhan, A. A., Fedoruk, A. G., "Correlation Between Individual Distinctions of Functional Asymmetry of Cerebral Hemispheres and Pilot Performance," 1(43).

Dashin, S. A., Marennyy, A. M., Gertsen, G. P., "Measurement of Charge and Energy Spectra of Heavy Nuclei Aboard Cosmos-936 Artificial Earth Satellite," 3(70).

Doroshev, V. G., Lapshina, N. A., Kirillova, Z. A., Kulikov, O. B., Kaliberdin, A. V., Ponomarev, S. I., "Comparative Assessment of Circulatory Reaction During Work in Weightlessness and in Salyut Station Mockup," 5(38).

Ioseliani, K. K., Narinskaya, A. L., Khisambeyev, Sh. R., "Contrology Used for Integral Assessment of Mental Work Capacity," 4(32).

Isupov, V. G., Maksimov, D. G., Polyakov, B. I., "Reaction to Diminished Circulating Blood Volume in Individuals Who Are Susceptible and Insusceptible to Motion Sickness (Seasickness)," 3(46).

Kalandarova, M. P., Pochukayeva, L. S., "Morphology and Coagulant Function of Human Blood System During Long Exposure to Low Ammonia Concentrations in a Sealed Environment," 4(39).

Kamenskiy, Yu. N., "Some Features of Evaluation of Work Capacity and Fatigue in Helicopter Pilots," 1(55).

Kamenskiy, Yu. N., "Dynamics of Functional State of Heavy Transport Helicopter Pilots in the Course of Flight Shift," 4(30).

Karpov, A. N., Zinov'yev, L. A., "Slow Waves of Cardiac Rhythm in Healthy Man Under Different Conditions," 3(30).

Katkov, A. Yu., Chabdarova, R. N., Pravetskiy, N. V., Vtoryy, S. A., Lenskiy, V. V., Titov, A. A., "Comparative Evaluation of Pressure Chamber Conditioning and Man's Adaptation to Hypoxia at High Altitude," 1(74).

Katkov, V. Ye., Chestukhin, V. V., Nikolayenko, E. M., Gvozdev, S. V., Rumyantsev, V. V., Guseynova, T. M., Yegorova, I. A., "Central Circulation in Healthy Man During 7-Day Head-Down Hypokinesia," 5(45).

Kwetnansky, R., Blazicek, P., Tigranyan, R. A., "Activity of Rat Adrenal Medulla After Flight Aboard Cosmos-1129 Biosatellite," 4(44).

Kwetnansky, R., Tigranyan, R. A., "Catecholamine Content of Rat Blood After Flight Aboard Cosmos-936 Biosatellite," 1(80).

Kwetnansky, R., Tigranyan, R. A., Torda, T., "Catecholamines and Enzymes of Their Metabolism in Rat Myocardium After Flight Aboard Cosmos-936 Biosatellite," 3(66).

Kislyakov, V. A., Stolbkov, Yu. K., "Significance of Vestibular Asymmetry to Genesis of Vestibular Dysfunction," 1(64).

Klimovskaya, L. D., Maslova, A. F., "Effect of Long-Term Exposure to High-Intensity Steady Magnetic Field on Activity of Adrenergic and Cholinergic Systems." 6(71).

Kozlovskiy, A. P., Stupakov, G. P., Dryannykh, V. P., Arsent'yev, A. B., Chuntul, V. V., "Significance of Bone Density to Spinal Trauma Related to Pilot Ejection," 1(62).

Komolova, G. S., Troitskaya, Ye. N., Yegorov, I. A., Tigranyan, R. A., "Effect of Stress on Nucleic Acid Metabolism in Rat Spleen and Liver Following Flight Aboard Cosmos-1129 Biosatellite," 5(66).

Kornilova, L. N., Kravchenko, S. L., Smirichevskiy, L. D., Belonogov, A. A., "Effect of Optokinetic Stimulation on Operator's Functional State and Professional Work Capacity," 4(17).

Kornilova, L. N., Shakhiyeva, V. A., Yakovleva, I. Ya., "Optokinetic Factors and Development of Seasickness Symptoms", 1(67).

Kostyuchenkov, V. N., Yasnetsov, V. S., "Effect of Drugs on Development of Stress Reaction in Rats Exposed to Acoustic Stimulus," 6(50).

Kotovskaya, A. R., Vil'-Vil'yams, I. F., Zborovskaya, V. I., Andreyeva, V. G., Golovkina, O. L., Krupina. T. N., Yarullin, Kh. Kh., Artamonova, N. P., "Endurance of +Gz Forces by Middle-Aged People Before and After 7-Day Immersion," 3(40).

Kotovskaya, A. R., Gavrilova, L. N., Galle, R. R., Glavacka, F., Schalling, M., Duda, P., "Human Equilibrium During Rotation at Different Levels of Hypergravity," 6(32).

Kreydich, Yu. V., Repin, A. A., Barmin, V. A., Kozlovskaya, I. B., "Effect of Immersion Hypokinesia on Characteristics of Human Eye and Head Movements During Gaze Fixation Reaction," 5(41).

Krupina, T. N., Tizul, A. Ya., Kuz'min, M. P., Tsyganova, N. I., "Clinicophysiological Changes in Man During Long-Term Antiorthostatic Hypokinesia," 2(29).

Krylova, N. V., Bokovikov, A. K., "Study of Operator's Verbal Information in the Course of Complicated and Combined Activity," 4(25).

Kuznetsov, V. I., "Seismocardiographic Evaluation of Contractile Function of Myocardium of Hypokinetic Rats," 4(35).

Kurkina, L. M., Tigranyan, R. A., "Nitrogen Compound Levels in Tissues of Rat Cerebral Hemispheres and Cerebellum After Flight Aboard Cosmos-1129 Biosatellite," 3(68).

Lapa, V. V., Lemeshchenko, N. A., "Influence of Orientation Method on Quality of Pilot's Spatial Orientation," 1(45).

Levashov, M. M., Tumakov, A. I., "Nystagmometry of Optovestibular Interaction," 3(51).

Leutin, V. P., Nikolayeva, Ye. I., "Determination of Psychophysiological Criterion for Predicting Effectiveness of the Adaptation Process," 6(58).

Litsov, A. N., "Sleep, Circadian Cycles of Physiological Functions and Parameters of Human Work Capacity on First Day After Changing From Altered to Usual Sleep-Waking Cycle," 3(8).

Mailyan, E. S., Buravkova, L. B., Kokoreva, L. V., "Energetic Reactions in Rat Skeletal Muscles After Spaceflight Aboard Cosmos-936 Biosatellite," 6(34).

Manovtsev, G. A., Korsakov, V. A., Odinokov, G. I., Stepanov, V. A., "Man's Adaptive Reactions to Acoustic Parameters of Isolated Habitats," 2(76).

Markelov, V. V., Chernykh, I. V., "Direct-Reading Dosimeters Used for Monitoring Radiation in Salyut Stations," 5(81).

Matveyev, Yu. G., Kamenskiy, Yu. N., "Physiological and Hygienic Rating of Transport Helicopter Vibration Damper," 1(58).

Minkova, M. I., Nikolov, I. T., Datsov, Ye. R., Pantev, T. P., Tenchova, V. B., "Effect of +Gx Acceleration and Adeturon on Nucleic Acid Content and Other Parameters of Mouse Peripheral Blood," 4(58).

Misurova, E., Tigranyan, R. A., Sabova, T., Praslicka, M., "Changes in Rat Tissue Deoxyribonucleoprotein and Nucleic Acids Following Flight Aboard Cosmos-1129 Biosatellite," 4(49).

Nevzgodina, L. V., Maksimova, Ye. N., "Cytogenetic Effects of Heavy Charged Particles of Galactic Cosmic Radiation in Experiments Aboard Cosmos-1129 Biosatellite," 4(67).

Nemet, Sh., Tigranyan, R. A., "Activity of Some Rat Liver Enzymes Following Flight Aboard Cosmos-936 Biosatellite," 1(77).

Nekhayev, A. S., Degtyarev, V. A., Bednenko, V. S., Kirillova, Z. A., "Feasibility of Simulating Hemodynamic Effects of Weightlessness With Use of Positive Pressure," 5(54).

Nikolayeva, T. N., Guseva, Ye. V., Tashpulatov, R. Yu., Syrykh, G. D., "Relationship Between Microflora and Immunity of Cosmonauts Carrying Staphylococcus Aureus in the Nasal Cavity," 1(40).

Ozerova, O. Ye., Asyamolova, N. M., Kochetov, A. K., "Percutaneous Measurement of Partial Oxygen Tension and Local Blood Flow in Man During Orthostatic Test," 4(41).

Omel'yanets, N. I., Lashkareva, V. I., Shabatura, N. N., Kucherov, I. S., "Hygienic Evaluation of New Types of Rubber to be Used in Water Supply Systems Exposed to High Temperatures and Active Chemicals," 2(70).

Plakhuta-Plakutina, G. I., Savina, Ye. A., Belkaniya, G. S., Tavadyan, D. S., Dmitriyeva, N. P., Amirkhanyan, Ye. A., Smirnova, R. S., "Morphological Distinctions of Macaca Rhesus Monkey thyroid Under Normal and Various Types of Hypokinetic Conditions," 4(52).

Polyakova, A. P., Yegorov, A. D., Alferova, I. V., "Dynamics of Left Ventricular Systolic Phase Structure During Long-Term (140-185 Days) Spaceflights," 3(25).

Popov, I. G., Latskevich, A. A., "Effect of 48-Day Flight on Blood Amino Acid Levels in Salyut-5 Crew," 2(14).

Popov, I. G., Latskevich, A. A., Potkin, V. Ye., Lozinskiy, P. A., Romanova, I. A., Kolesnikova, L. I., "Dynamics of Nutritional Status During Simulation of Long-Term Aircraft Flights," 1(49).

Popov, I. G., Lozinskiy, P. A., Latskevich, A. A., Romanova, I. A., "Metabolic Distinctions Related to Intake of Low-Calorie 'Survival' Rations Consisting Only of Readily Assimilated Carbohydrates," 3(16).

Potapov, P. P., "Condition of Rat's Connective Tissue During Long-Term Hypokinesia and in the Recovery Period," 3(73).

Prokhonchukov, A. A., Desyatnichenko, K. S., Tigranyan, R. A., Komissarova, N. A., "Mineral Phase and Protein Matrix of Rat Osseous Tissue Following Flight Aboard Cosmos-1129 Biosatellite," 2(61).

Prokhonchukov, A. A., Peschanskiy, V. S., "Stereological Analysis of Rat Bone Tissue After Flight Aboard Cosmos-1129 Biosatellite," 4(47).

Radayeva, I. A., Rossikhina, G. A., Usacheva, V. A., Poyarkova, G. S., Shul'kina, S. P., "Biological Value and Shelf Life of Cultured Dairy Products in the Diet of Cosmonauts," 2(23).

Sergeyev, I. N., Blazheyevich, N. V., Belakovskiy, M. S., Spirichev, V. B., Ushakov, A. S., "Role of 24,25-Dihydroxycholecalciferol in Bone Mineralization in Hypokinetic Rats," 5(74).

Serebrovskaya, T. V., "Evaluation of Degree of Genetic Determination of Human Cardiorespiratory Reactions to Hypoxia and Hypercapnia," 6(54).

Shimko, I. A., "Neurophysiological Characteristics of Sensorimotor Cortex of Rats Submitted to Early Motor Deprivation and Conditioning," 2(64).

Shipov, A. A., Tabakova, L. A., "Nystagmic Reactions of Rats After Flight Aboard Cosmos-1129 Biosatellite," 6(45).

Shubin, V. S., Anzimirov, V. L., Gaganov, Ya. K., Korniyenko, V. N., "Regulation of Cerebral Circulation in Erect Position," 3(35).

Yakovleva, I. Ya., Kornilova, L. N., Tarasov, I. K., Alekseyev, V. N., "Results of Studies of Cosmonauts' Vestibular Function and Spatial Perception," 1(20).

Clinical Studies

Rozenblyum, A. S., "Short-Term Acoustic Ad'ptation as a Criterion of Resistance of the Auditory System to Noise," 6(76).

Methods

Anisimov, B. V., Kuz'menko, G. N., Golubeva, T. I., "Modification of Method for Assaying Ozone by the Diacetyl Dihydrolutidine Reaction," 3(89).

Belkaniya, G. S., Lemondzhava, N. I., "Diagnostic Use of Enzymatic Test in Experiments on Monkeys," 4(75).

Ilyukhin, A. V., Burkovskaya, T. Ye., Shafirkin, A. V., Klyuchanskaya, N. V., "Methodological Aspects of Testing Erythrocyte Balance by Counting Incubated Reticulocytes," 3(86).

Kotovskaya, A. R., Savina, Ye. A., Mokrousova, A. V., Alekseyev, Ye. I., Markin, A. S., Anichin, V. F., Shipov, A. A., Ayzikov, G. S., "Preparation of Labyrinthectomied Animals for Flight Aboard Cosmos-936 Biosatellite," 3(83).

Lebedeva, T. Ye., Yakimova, I. V., Nazarov, N. M., Chizhov, S. V., "Influence on Urea Hydrolysis of Typical Mic oflora of Urine and Pressurized Habitats," 1(84).

Marennyy, A. M., "Identification of Heavy Nuclei in Radiobiological Experiments in Space," 5(84).

Nalimova, T. A., Savinkov, A. B., Kafanov, R. V., "Measurement of Vestibular Asymmetry in Rotation Tests," 4(71).

Sokolova, I. V., Yarullin, Kh. Kh., "System for Automatic Analysis of Rheoencephalograms," 4(81).

Tukshaitov, R. Kh., Maksimov, D. G., "Amplitude Distortions on Rheograms When Recorded Simultaneously on Several Channels," 6(80).

Turbasov, V. D., Golubchikova, Z. A., "Comparative Evaluation of Informativeness of Three Corrected Orthogonal Leads and Twelve Conventional EKG Leads in Conducting Functional Tests," 4(72).

Brief Reports

Akhmedov, R., Nasyrova, A. M., "Effect of High Ambient Temperature on Carbohydrate Metabolism in Rat Liver and Skeletal Muscles," 3(92).

Gorgiladze, G. I., Ritter, S. P., Sarychev, V. N., Sablin, V. N., "Gaze Fixation Used to Suppress Vestibular Nystagmus," 5(90).

Gorlov, V. G., Neyman, O. V., "Hematological Lesions as a Function of Dosage of Long-Term Radiation," 1(86).

Davydova, N. A., Tigranyan, R. A., "Sympathoadrenal System of Cosmonauts Following 7-day Flights," 2(88).

Degtyarev, V. A., Dovzhenko, Yu. M., Larionova, L. A., Doroshev, V. G., Lapshina, N. A., "Preflight Examination Results Used to Forecast Cosmonaut Endurance of Orthostatic Tests After Spaceflight," 4(83).

Dolgun, Z. S., Meshcheryakova, S. A., Belakovskiy, M. S., Legen'kov, V. I., "Serotonin and Histamine Metabolism in Cosmonauts," 1(89).

Domaczuk, J., "Changes in Some Biochemical Parameters of Blood as a Function of Program of Accelerations," 6(87).

Kwetnansky, R., Tigranyan, R. A., "Epinephrine and Norepinephrine Concentrations in Rat Cardiac Ventricles and Atria After Flight Aboard Cosmos-1129 Biosatellite," 4(87).

Kwetnansky, R., Tigranyan, R. A., "Rat Blood Plasma Corticosterone After Flight Aboard Cosmos-1129 Biosatellite," 4(89).

Kwetnansky, R., Tigranyan, R. A., Jindra, A., Viting, T. A., "Renin-Angiotensin-Aldosterone System and Electrolyte Metabolism in Rat Blood After Flight Aboard Cosmos-1129 Biosatellite," 4(85).

Krivobok, N. M., Gaydadymov, V. B., Nosov, V. V., Ter-Minas'yan, G. G., "Quantitative Evaluation of Effects of Physicochemical and Technological Factors on Water Regeneration Process," 5(91).

Mileva, M., Ivanov, B., Bulanova, M., Pantev, T., "Effect of Steady Magnetic Field on Human Lymphocytes," 6(86).

Misurova, E., Tigranyan, R. A., Kropaceva, K., Praslicka, M., "Deoxyribonucleoprotein and Nucleic Acid Content of Rat Tissues After Flight Aboard Cosmos-936 Biosatellite," 4(91).

Nekhayev, A. S., Degtyarev, V. A., Bednenko, V. S., "Venous Pressure as an Indicator of Circulating Blood Volume," 2(91).

Tigranyan, R. A., Macho, L., Kwetnansky, R., Kalita, N. F., "Hormone Concentration in Rat Blood Plasma After Flight Aboard Cosmos-936 Biosatellite," 6(84).

Chulman, Yu., Kwetnansky, R., Tigranyan, R.A., "Serotonin Concentration in Isolated Nuclei of the Hypothalamus, Limbic System and Brain of Rats Following Flight Aboard Cosmos-1129 Biosatellite," 5(87).

Shabayev, V. P., "Effects of Low-Intensity Electromagnetic Fields on Human and Animal Erythrocytes," 3(91).

Skottova, N., Macho, L., Palkovic, M., Tigranyan, R. A., "Effect of Spaceflight on Lipogenesis and Lipolysis in Rats," 6(82).

Yakovleva, I. Ya., "Electrometric Characteristics of Man's Gastrolingual Reflex," 2(92).

Discussions

Kamenskiy, Yu. N., "Vibration and Assessment of This Flight Factor by Pilots," 3(94).

Current Events and Information

Maksimov, A. A., "First All-Union Symposium on 'Problems of Evaluating and Forecasting Man's Functional States in Applied Physiology,'" 1(91), 2(94), 4(93).

Book Reviews

Ioseliani, K. K., "History of Soviet Aviation Psychology" edited by K. K. Platonov, "Nauka", Moscow, 1981, 319 pages, 5(93).

Katkov, V. Ye., "Gravitational Physiology. Advances in Physiological Sciences, Proceedings of the 28th International Congress of Physiological Sciences," edited by J. Hideg, O. Gazenko, Pergamon Press and Akademiai Kiado, Budapest, Vol 19, 1980, 316 pages, 134 figures, 37 tables, 1(94).

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Fofanov, V. I., "Space Gastroenterology," by V. Smirnov, A. M. Ugolev, 4(94).

Anniversaries

"80th Birthday of Andrey Vladimirovich Lebedinskiy (1902-1982)," 5(94).

Obituaries

"Avetik Ignat'yevich Burnazyan (1906-1981)," 1(96).

"P. A. Campbell," 5(96).

Abstracts of Articles Filed With the All-Union Scientific Research of Medical and Medicotechnical Information--Nos 2 and 4.

10,657
CSO: 1849/2

AUTHOR INDEX [for 1982]

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 6, Nov-Dec 82 (signed to press 12 Oct 82) pp 94-96

[Author index]

10,657
CSO: 1849/2

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